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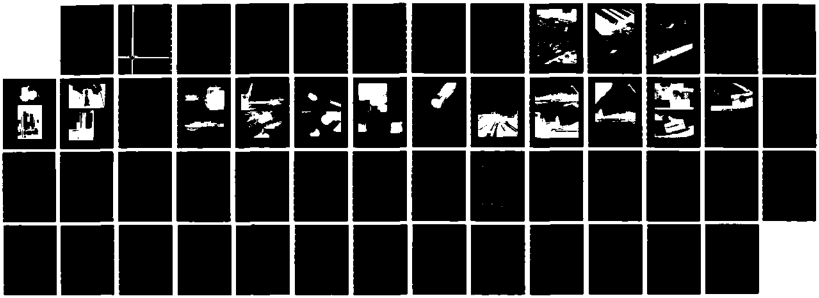

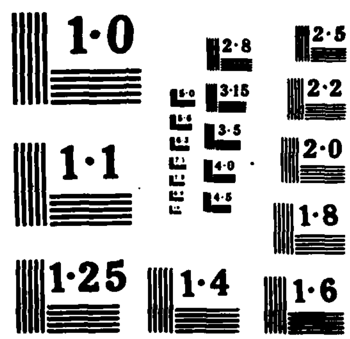
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Report 2433

TEST REPORT
for the
EVALUATION
of the
PIPELINE OUTFIT, PETROLEUM (POP)

Prepared by the
FUELS HANDLING R&D TEAM
BELVOIR RD&E CENTER

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5 May 1986

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Belvoir Research, Development & Engineering Center
Fort Belvoir, Virginia 22060-5606

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The Pipeline Outfit, Petroleum (POP) is a commercial pipe joining system consisting of an hydraulic joining press that swages a plain pipe section into a special coupling. The Action Officer Work Group (AOWG) for the improvement of petroleum systems tasked the Belvoir RD&E Center to test the POP for its possible use in the Southwest Asia Pipeline Deployment Operational Project (SWAPDOP).

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Per Mr. Frederick Balling, ABRDC/STRBE-FSP

Test Report for the Evaluation of the Pipeline Outfit, Petroleum (POP)

1. INTRODUCTION:

At the suggestion of Willbros-Butler Engineering, Inc. (WBEI), the Action Officer Work Group (AOWG) for the improvement of petroleum systems tasked the Belvoir Research, Development, and Engineering Center (BRDEC) to test the POP pipe-coupling connection so that WBEI can evaluate its applicability for gap and/or river crossings relative to the pressure ratings of the Southwest Asia Pipeline Deployment Operational Project (SWAPDOP). The BRDEC Fuels Handling R&D Team tested the connection to find its hydrostatic pressure, natural bend, tensile pull, and flexure limits. The test samples consisted of combinations of six-inch, MD261 aluminum assault pipe, both plain end and double-rolled-groove end; six-inch, Grade B, Schedule 40 steel pipe; and Positive Seal couplings, both Series 800 and Schedule 40.

This test report starts with a background and system description for those readers unfamiliar with the POP. The body of the report contains the test objectives, test designs, photographs, data, and discussion of results. We end with conclusions. Test Plan, figures, and diagrams are included in the appendices.

2. BACKGROUND:

The DA commissioned a study, "Bulk Distribution in a Theater of Operations," and the Quartermaster School (QMS) conducted it in June 1977. The study recognized the inadequacies of the present system, and the QMS recommended that the POP be integrated as a part of the Army pipeline deployment system. With that recommendation, BRDEC conducted an in-depth market survey during 1978-1979 to determine the state-of-the-art in pipe-joining technology and to compare that technology with military needs. BRDEC concluded that commercially available pipe-joining methods, using an hydraulic press, would satisfy the Army's pipeline construction requirements.

QMS and BRDEC visited commercial sources and found that a joining press used to drive a pipe section into a coupling could satisfy the Army's need if the machine's weight was reduced to meet air transportability restrictions. During 1980, BRDEC let a contract to evaluate the hardware modifications necessary to make the commercial unit air transportable. This effort showed that off-the-shelf components and materials could be used for an Army version. For weight reduction, the frame of the joining press could be made from structural aluminum. BRDEC determined that a press with an aluminum frame could join the Army's thin-wall, aluminum pipe (0.109- & 0.150-in. wall).

During the site visits and the evaluation contract, the QMS drafted a Required Operational Capability (ROC), and the Training and Doctrine Command (TRADOC) approved it. BRDEC issued a competitive solicitation for the fabrication of the Army's design of the hydraulic joining press. In the fall of 1981, the contract was awarded to ICO Positive Seal, Inc. of Odessa, Texas.

In 1982, BRDEC held a special In-Process Review (IPR) and received approval of a Non-Developmental Item (NDI) procurement strategy with limited testing to assess operational and logistical supportability. During the summer and fall of 1982, the Test and Evaluation Command (TECOM) and the US Army Armor and Engineer Board conducted the testing at Aberdeen Proving Ground, MD and Fort Pickett, VA, respectively. The tests proved that target lay rates could be met during daylight operations.

After the testing, BRDEC scheduled a Type Classification (TC) IPR for the fall of 1983. But before the TC IPR could be held, TRADOC raised the following issues:

- When would the final Basis of Issue Plan (BOIP) and Qualitative and Quantitative Personnel Requirements Information (QQPRI) be approved?
- What Table of Organization and Equipment (TO&E) units would be involved?
- What would be the equipment allocation to these units?
- What MOSs would be involved?

However, the key issue was whether the need for the system still existed. With these issues unresolved, TRADOC postponed the TC IPR indefinitely.

During 1984-1985, the AOWG for the SWAPDOP expressed a renewed interest in the POP for use in gap, river, and tunnel crossings. At the suggestion of WBEI, the AOWG tasked the BRDEC Fuels Handling R&D Team to test the newer 0.188-inch wall, aluminum assault pipe that will be used for SWAPDOP. During the summer and fall of 1986, troops are scheduled to perform a System Integration Test and a Force Development Test and Evaluation at the Yakima Firing Range to determine the POP's capability for crossings.

If WBEI decides that the POP can be used for SWAPDOP, TRADOC should renew the need and BRDEC should reschedule a TC IPR. Note that the program has undergone several changes since its start:

— The wall thickness of the aluminum assault pipe has increased from 0.109 inches to 0.188 inches, requiring a heavier-duty press.
— The couplings now are coated with Neutra Rust DL at the factory, eliminating field application of the epoxy resin.
— Most importantly, the need has changed from a primary pipe deployment method to a secondary one that uses the POP for crossings only.

3. SYSTEM DESCRIPTION:

The POP consists of the pipe-joining press, Positive Seal couplings, and standard pipe sections.

The pipe-joining press is hydraulically powered and can be either mobile or stationary. In normal pipeline construction, the press is suspended from a side-boom crane mounted on a D7 bulldozer. The dozer moves forward as each new pipe section is added. If a crossing is necessary, the press can be set up on one side of the gap, river, or tunnel, and the pipeline pulled through as each new section is added.

ICO Positive Seal, Inc. designed a press to assemble test samples for swaging six- and eight-inch aluminum pipe of 0.109- to 0.150-inch wall thickness into a Series 800, Positive Seal coupling. The frame of the press is aluminum; and 5.0-inch diameter, hydraulic cylinders drive the travelling slips that grip the pipe. ICO also makes a heavier-duty press with 7.0-inch cylinders and a steel frame.

The Positive Seal coupling is a steel collar that has the inside wall tapered and serrated (see Figure 1, Appendix B). As the press drives the pipe into the coupling, the taper creates a swaging action against the pipe wall, and the serrations grip the pipe surface. One side of the coupling is the mirror image of the other.

Prior to assembly, the inside of the coupling is coated with either an epoxy resin or a nylon-based compound called Neutra-Rust DL. The epoxy is difficult to use and must be mixed and applied in the field as construction proceeds. Neutra-Rust DL is applied by the manufacturer, and no extra field labor is necessary. The coating lubricates the coupling/pipe interface during insertion and helps seal the completed joint against leaking. All of the test couplings were coated with Neutra-Rust DL.

BRDEC and WBEI have considered two coupling designs: Series 800 and Schedule 40. Only the Series 800 couplings were available at the start of the testing program, thus, they were the primary subjects. Series 800 couplings are designed for use with light-wall aluminum pipe, and the serrated part of one side of the coupling is 2.50 inches long. The Schedule 40 couplings are designed for use with steel and heavier-wall aluminum pipe and have 4.875 inches of serrations per side. Note that if a double-rolled-grove pipe end is fully inserted into the Series 800 coupling, the grooves lie beyond the serrations. For the Schedule 40 coupling, one of the grooves lies in the serrated portion, but there are still approximately four inches of serrations (see Figure 1, Appendix B).

Depending on the press, aluminum or steel pipe of American Petroleum Institute outside diameters can be used. Because the pressure ratings of SWAPDOP are 650 psi for normal operation and 900 psi for emergency operations, the six-inch, aluminum assault pipe (0.188-inch wall, T6, 6063, MD261 alloy) must be used instead of the aluminum pipe with 0.109- or 0.150-inch walls.

4. TEST OBJECTIVES:

The goal of the test program was to determine the integrity of the POP joint when subjected to: (1) hydrostatic pressure and (2) forces exerted on a pipeline while it is carried or pulled across a gap, river, or the like.

5. TEST DESIGN:

At the recommendation of WBEI, the BRDEC Fuels Handling R&D Team conducted hydrostatic pressure, natural bending, tensile pull, and flexure tests. For descriptions of test objectives, designs, procedures, and acceptance criteria, refer to Appendix A: Plan of Test.

6. TEST RESULTS:

a. Hydrostatic Pressure (see Table 1):

None of the samples leaked at normal, emergency, and proof pressures (650, 900, and 1,064 psi, respectively). We intended these tests to be destructive, and we caused six bursts: four in aluminum and two in steel. Three of the bursts in the aluminum samples (1,800, 1,800, 1,920 psi) resulted from the pipe wall limits. The fourth burst in aluminum (1,980 psi) happened simultaneously in the pipe wall and at the coupling, but the wall split very close to the coupling and may have contributed to the coupling failure. The pipe in this sample had double-rolled-groove ends. (See Photo 1).

For both steel samples, the press could only push the pipe part of the way into the coupling. And in both cases, the pipe gradually slid out of the coupling at 2,000 psi.

TABLE 1: HYDROSTATIC PRESSURE TEST RESULTS

Test No.	Cplg No.	Cplg Type	Pipe Type	Pipe End	Sub A Insert Depth (in)	Sub B Insert Depth (in)	650 psi	900 psi	1,064 psi	Burst psi	Failure occurred at:	Remarks
1	3	S800	MD261	PE	6.625	6.625	OK	OK	OK	1,800	Pipe wall	See Photo 2
2	4	"	"	"	"	"	"	"	"	1,800	Pipe wall	See Photo 3. Failure at groove.
3	5	"	"	"	"	"	"	"	"	2,000	None	Guage limited to 2,000 psi.
4	8	"	"	DRG	"	"	"	"	"	2,000	None	Deformation at groove.
5	7	"	"	"	"	"	"	"	"	1,920	Pipe wall	See Photo 4.
6	6	"	"	"	"	"	"	"	"	1,980	Pipe wall & Cplg	See Photo 5. Failure at pipe wall may have caused coupling failure.
7	29	"	Steel	PE	5.25	5.75	"	"	"	2,000	Cplg	Did not have full insertion.
8	15	"	"	"	4.50	4.25	"	"	"	2,000	Cplg	See Photo 6. Did not have full insertion.

PE = Plain End DRG = Double-Rolled-Groove ends S800 = Series 800 MD261 = Aluminum Assault Pipe

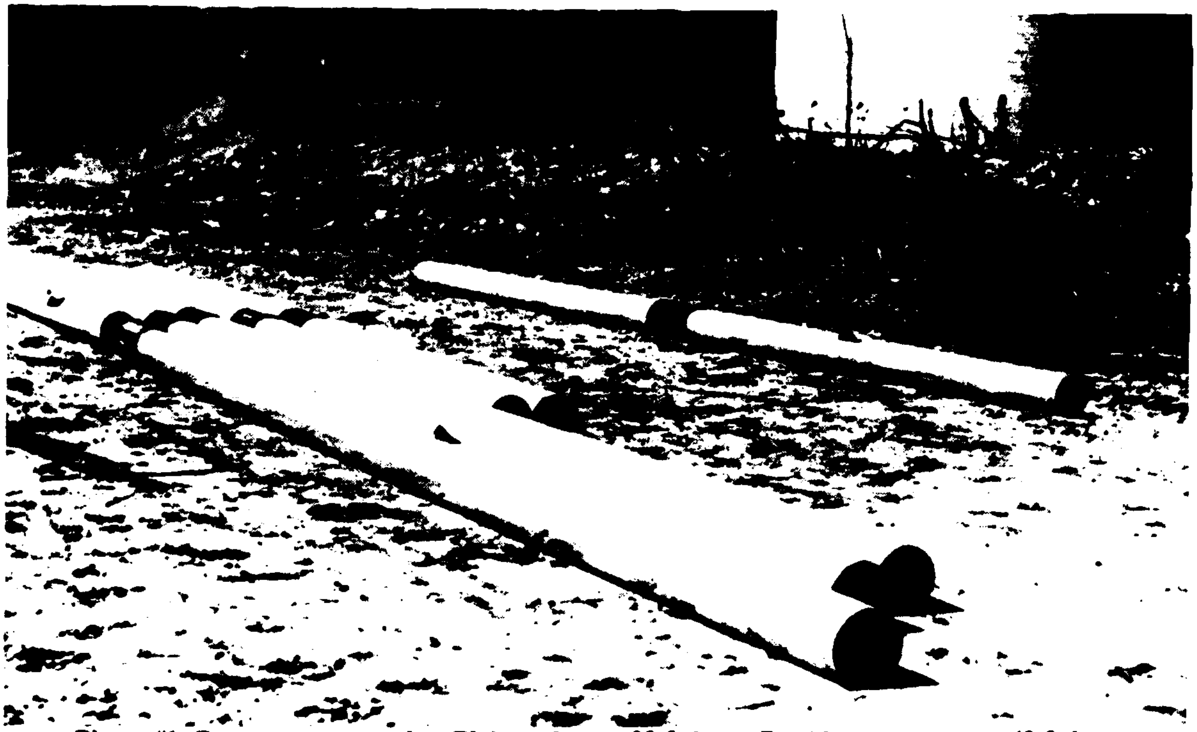


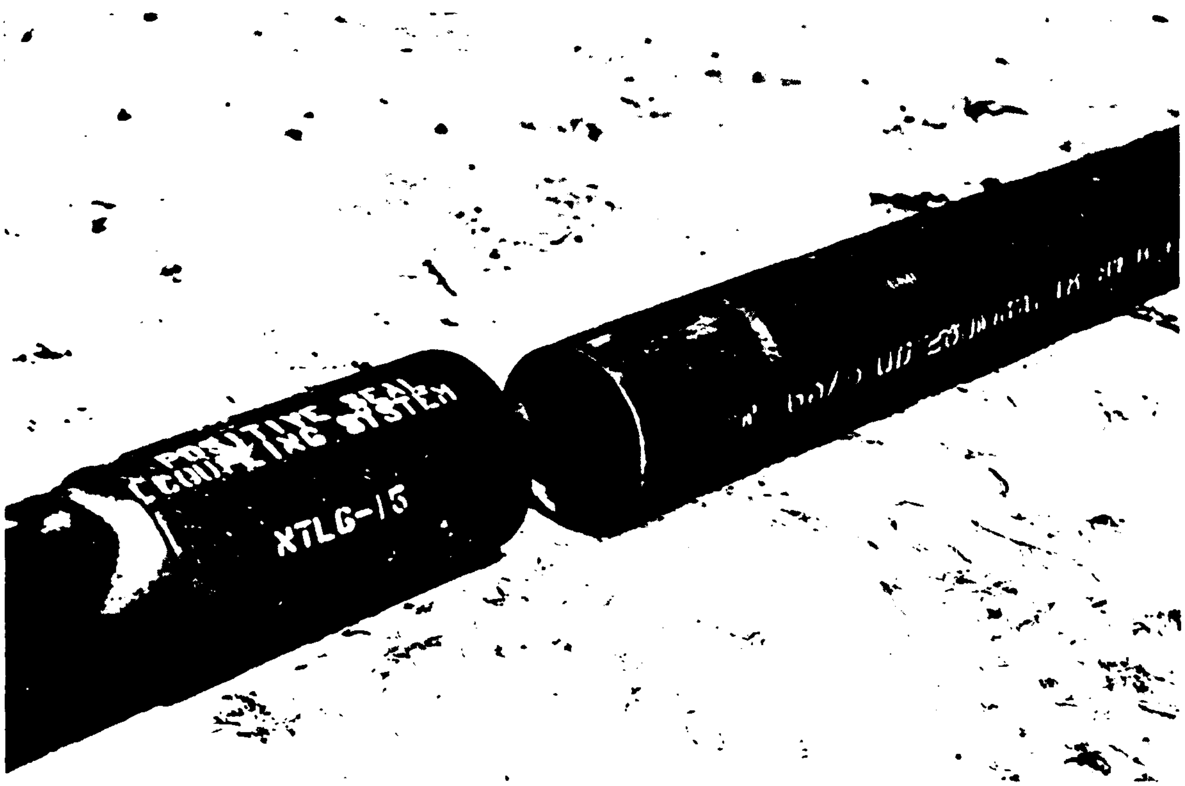
Photo #1: Pressure test samples. Plain end were 20 ft long. Double-grooved were 40 ft long.

Photo#2: Hydrostatic pressure test #1. Pipe wall burst at 1,800 psi.

Photo #3: Hydrostatic pressure test #2. Pipe wall failure at groove at 1,800 psi.

Photo#4: Hydrostatic pressure test #5. Pipe wall burst at 1,920 psi.

Photo #5: Hydrostatic pressure test #6. Pipe wall burst at 1,980 psi with coupling 5 failure.



Photo#6: Hydrostatic pressure test #8. Coupling failure at 2,000 psi.

b. Natural Bending (see Table 2; and Figure 2, Appendix B)

WBEI suggested that sample hydrostatic pressure be 650 psi.

All runs were successful at this pressure. However, we pressured each sample to 900 psi, and one plain-end, aluminum pipe slid out of the coupling after five minutes. Note that one double-rolled-groove aluminum sample withstood 900 psi, although one pipe was partially inserted.

We didn't test the steel samples because the joining press could insert the pipe to about one inch of serrated engagement, and the samples came apart as they were being lifted into place. A fork lift was used to pick up the sample, and about 45,000 ft-lb of torque was exerted on the middle connection.

TABLE 2: NATURAL BENDING TEST RESULTS

Test No.	Cplg No.	Cplg Type	Pipe Type	Pipe End	Sub A Insert Depth (in)	Sub B Insert Depth (in)	Hydrostatic Pressure (psi) 650	900	Height Above Ground (ft)	Remarks
1	24	S800	MD261	PE	6.625	6.625	OK	OK	6	
	31	"	"	"	"	"	"	Failure	1	Pipe blew out after 5 min at 900 psi.
	34	"	"	"	"	"	"	OK	0	
2	23	"	"	"	"	"	"	"	6	
	37	"	"	"	"	"	"	"	1	
	18	"	"	"	"	"	"	"	0	
3	17	"	"	DRG	5.50	"	"	"	6	Not full insertion.
	36	"	"	"	6.625	"	"	"	1	
	30	"	"	"	"	"	"	"	0	
4	25	"	"	"	"	"	"	"	6	
	12	"	"	"	"	"	"	"	1	
	11	"	"	"	"	"	"	"	0	Sub A heavily scored.

c. Tensile Pull - Lab (see Table 3):

Finding the proper method to anchor the aluminum pipe samples into the Baldwin tension/compression frame required several trials. To anchor the samples into the frame, we drilled two-inch holes through the pipe and/or coupling walls and slid a steel pin through the walls and the test jig. We made the first sample from two, short, aluminum pipe subs (cut off after assembly) and one coupling. When a load was applied, the aluminum pipe walls yielded before there was any movement between the pipe and the coupling (see Appendix C, diagram 4). Note that the steel pipe walls did not yield.

In the next attempt, we had reinforcement pads welded on the aluminum pipe. When the load was applied, the pipe wall cracked along the heat affected zone of the transverse weld, and there was no movement between pipe and coupling (see Appendix C, diagram 7).

Because of the low yield strength of the aluminum pipe wall, we made a sample from one pipe sub with a coupling on each end. We drilled the two-inch anchoring holes through the steel coupling walls, hoping the walls would withstand the tensile load. This configuration proved satisfactory. However, to fit the sample into the tension/compression frame, we had to cut the pipe sub too short to use the joining press. To overcome this, we inserted a long section of pipe into one coupling with the joining press, cut the pipe to length, and inserted the free end into the second coupling with the tension/compression frame. In all, we measured the insertion force for two series 800 and two schedule 40 couplings. For full insertion, the series 800 couplings needed 47,000 lb and 27,500 lb and the schedule 40 couplings needed 103,750 lb and 98,750 lb (see Appendix C, diagrams 8-10).

Results from the tests of samples made in the tension/compression frame indicated that the couplings were not properly aligned with the pipe subs during insertion. The resulting binding action may have deformed the pipe end, and less force was needed to pull the samples apart than to push them together.

Finally, we had aluminum reinforcement pads welded to the pipe ends again, but with no transverse welds. This arrangement proved satisfactory, and the tensile force needed to cause slippage between the pipe and coupling ranged from 28,500 lb to 86,500 lb. Note that exerting a tensile load of 28,500 lb is about the same as suspending 5,400 feet of aluminum pipeline. Because of the inconsistency and lack of explanatory data, the sample population will be increased by including from the other tests those pipe/coupling assemblies that remained intact. When we finish the tests, we will include the results in this report as an addendum.

TABLE 3: LAB TENSILE PULL TEST RESULTS

Test No.	Cplg No.	Cplg Type	Pipe Type	Pipe End	Sub A Insert Depth (in)	Sub B Insert Depth (in)	Pull-out Force (psi)	Slippage Occurred At:	Remarks See Photos 7 & 8 for test setup.
1	1	S800	Steel	PE	2.625	6.625	30,000	N/A	Sub A was not filed around edge. Test stopped to *increase load range.*
2	1	"	"	"	"	"	60,000	N/A	Test stopped to increase load range.
3	1	"	"	"	"	"	61,000	Sub A	See Photo 10, Sub A inserted only 2.625 inches.
4	2	"	MD261	"	6.625	6.625	28,500	None	Aluminum pipe wall failed at test jigs. See Photos 9 & 10.
5	1	"	Steel	"	N/A	6.625	86,500	Sub B	Same sample as runs 1,2, & 3 was cut off and redrilled through A side of coupling.
6	2	"	MD261	"	6.625	6.625	59,000	None	Same sample as run 4. Deformed portions of aluminum pipe wall were cut off, and reinforcement pads were welded on. Test stopped to increase load range.
7	2	"	"	"	"	"	79,250	None	Failure at heat affected zone along transverse welds.
8	9, 10	"	"	"	"	N/A	37,000	Cplg 10 Sub A	Pipe sub heavily scored. 5.5" of Cplg 9 inserted in press, remainder in comp. frame (47,000 lb req). Cplg 10 pushed on entirely in comp. fr. (27,500 lb req).
9	9, 13B	"	"	"	"	N/A	40,050	Cplg 9 Sub A	Same sample as Test 8. Damaged part cut off and Cplg 13 pushed on in lab (80,250 lb req).
10	N/A	Sc40	"	"	"	N/A	41,000	Sub B	Two Schedule 40 cplg pushed on in lab (103,750 & 98,750 lb req).
11	13	S800	"	"	N/A	6.625	75,000	Sub B	Same sample as Test 9. Damaged part cut off & reinforced (no transverse welds).
12	N/A	Sc 40	"	"	6.625	N/A	74,000	Sub A	One reinforced pipe sub and one Schedule 40 coupling.

*Refer to APPENDIX C: Stress vs. Strain Diagrams.

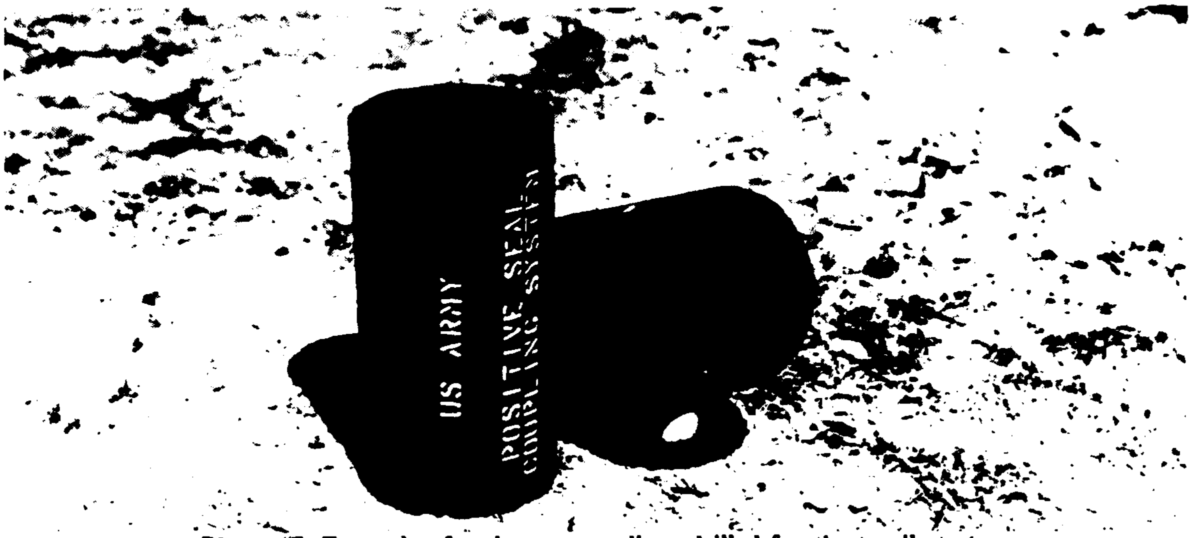
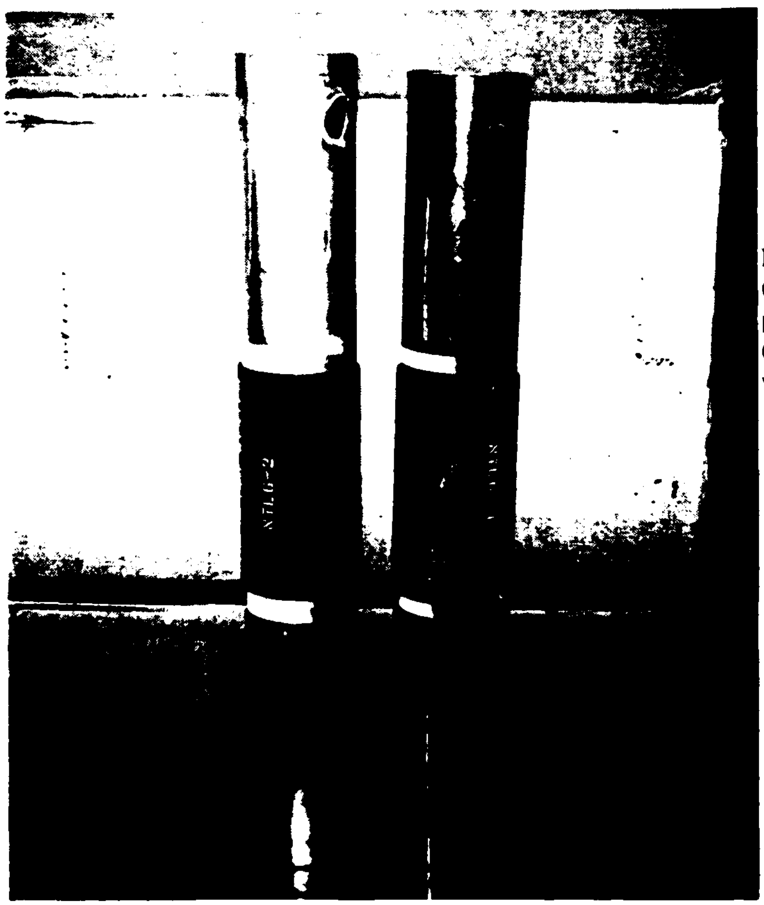


Photo #7: Example of end-most couplings drilled for the tensile tests.

Photo#8: Lab tensile test sample mounted in the Baldwin tensile test machine.

Photo #9: Pipe wall deformation at 28,000 lb of tensile stress Test #4.



Photo#10: Lab tensile test samples 1 (steel) and 2 (alum). Sample 1: slippage between coupling & pipe @ 61,000 lb. Sample 2: failure of pipe wall at test jig.

d. Tensile Pull - Field (see Table 4):

We intended to anchor one end of an eighty-foot pipeline assembly to a deadman, connect the other end to a load cell, and connect the load cell to a dynamometer truck with a chart recorder on board. As the truck applied the tensile load, a forklift would lift the pipeline up and down to simulate carrying a pipeline over a crossing. But, results of the lab tensile tests indicated that the dynamometer truck might not be able to pull with enough force to cause slippage at the pipe-coupling connection. Therefore, we substituted a D7 dozer with an hydraulic winch for the dynamometer truck and sacrificed the chart recording capability.

The load cell was designed to measure forces within specific ranges, and we tried to adjust those ranges as the hydraulic winch increased the tensile load. However, we could only determine that slippage between the pipe and coupling occurred at some force less than the maximum force of a particular range. The results seem to show that the up and down motion of the pipeline weakens the tensile strength of the joint.

TABLE 4: FIELD TENSILE PULL TEST RESULTS

Test No.	Cplg No.	Cplg Type	Pipe Type	Pipe End	Sub A Insert Depth (in)	Sub B Insert Depth (in)	Pull-Out Force psi	Slippage Occurred At:	*Remarks See Photos 11-13 for setup.
1	50	S800	MD261	PE	6.625	N/A	<40,000	None	
	21	"	"	"	6.625	6.625	"	Sub B	See Photo 14.
	14	"	"	"	"	"	"	None	
	22	"	"	"	"	"	"	"	
	49	"	"	"	N/A	"	"	"	
2	45	"	"	"	N/A	"	<52,000	None	
	38	"	"	"	6.625	"	"	"	
	33	"	"	"	"	"	"	"	
	32	"	"	"	"	"	"	Sub A	See Photo 15.
	48	"	"	"	N/A	"	"	None	
3	48	"	"	DRG	N/A	6.625	<40,000	None	
	20	"	"	"	6.625	"	"	"	
	35	"	"	"	"	"	"	Sub A	See Photo 16.
	40	"	"	"	"	"	"	None	
	39	"	"	"	"	"	"	"	
	41	"	"	PE	N/A	"	"	"	
4	48	"	"	DRG	N/A	6.625	<40,000	None	
	27	"	"	"	6.625	6.625	"	"	
	21	"	"	"	"	"	"	Sub A	See Photo 17.
	28	"	"	"	"	"	"	None	
	19	"	"	"	"	"	"	"	Sub 19B was Plain End.
	43	"	"	PE	N/A	6.625	"	"	

*See Photos 18 & 19, insertion of steel pipe into the Schedule 40 coupling.

Photo #11: Field tensile test showing setup and bending of the samples.

Photo#12: Field tensile test setup.

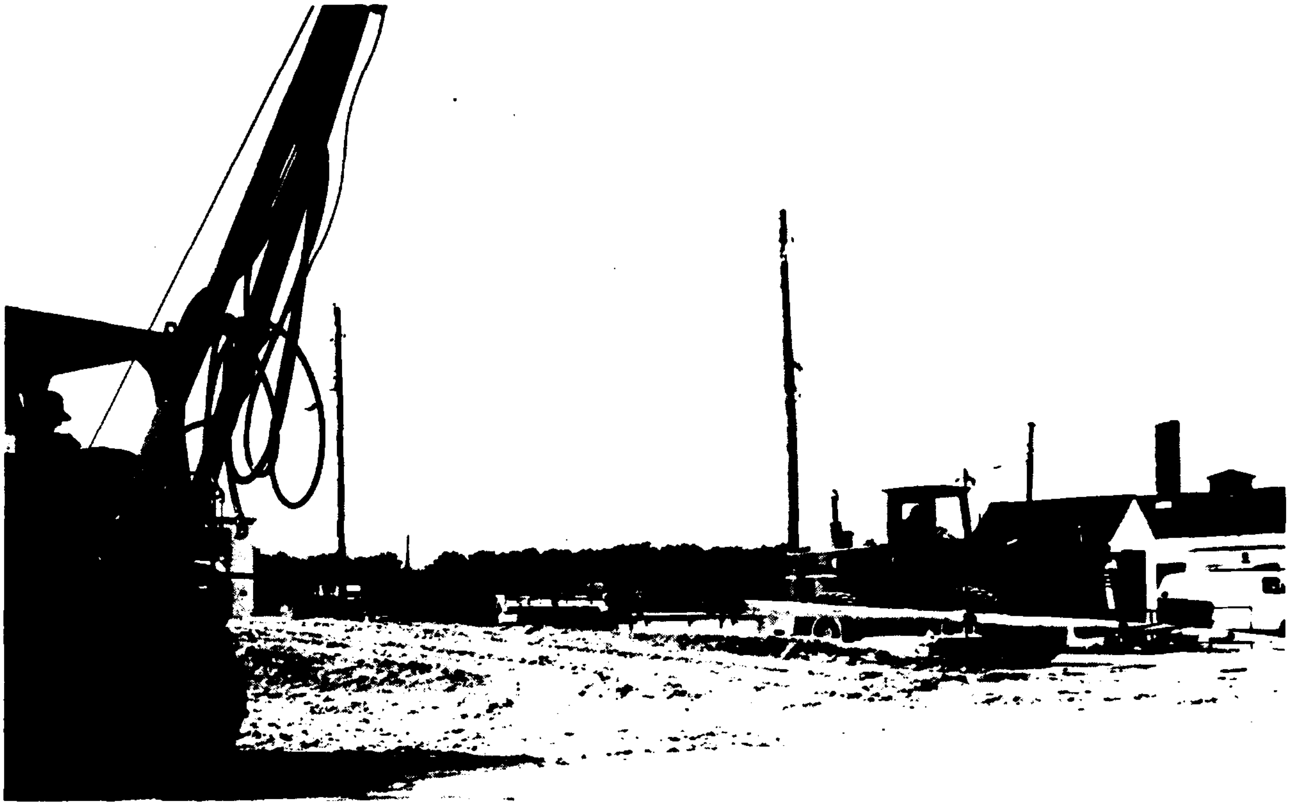
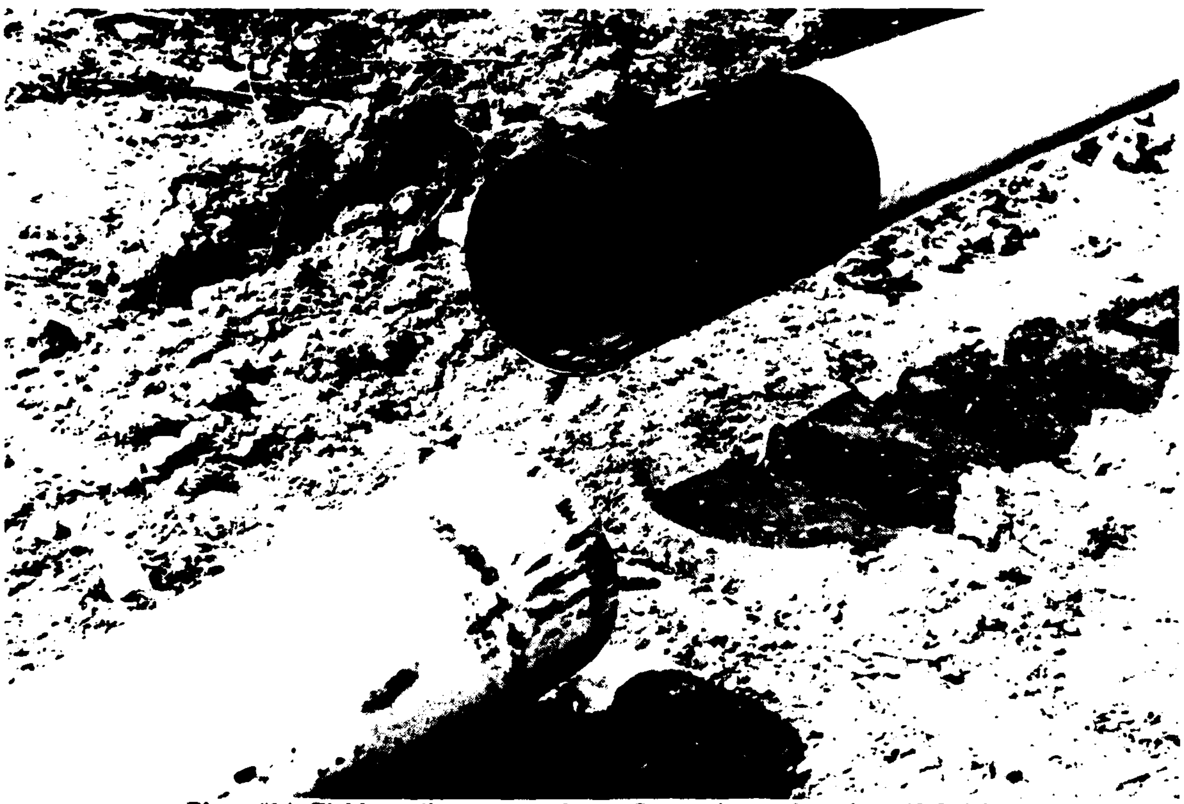


Photo #13: Field tensile test setup.



Photo#14: Field tensile test sample #1. Separation at less than 40,000 lb.

Photo #15: Field tensile test #2. Plain end aluminum pipe. Pull out at less than 52,000 lb

Photo#16: Field tensile test#3. Double-rolled-groove ends. Pull out at less than 40,000 lb.failure at 2,000 psi.

Photo #17: Field tensile test #4. Double-rolled-groove ends pull out at less than 40,000 lb.

Photo#18: Field tensile test#5. Steel Pipe & Schedule 40 coupling. Sample came apart because of poor insertion.

Photo #19: Field tensile test #5. Shows poor insertion depth.

e. Flexure (see Table 5 and Photos 20 through 26):

Because the tapered and serrated part of the Positive Seal coupling centers the pipe in the coupling, the pipe wall does not touch the coupling near the outer rim (see Appendix C, Figure 4). The aluminum assault pipe proved to be very flexible between the connections for applied bending moments, resulting in 15 feet of deflection in 50 feet of pipe. However, above this point the coupling walls began to bind against the pipe walls, deforming the pipe. At about 20 feet of deflection in 50 feet of pipe, the pipe moved inside the coupling, and the pipe walls were permanently deformed. During normal construction, we doubt that a crew would bend a pipeline so severely.

Note that there are three couplings in fifty feet of pipe, and there was no damage to the two joints farthest from the buried portion of the pipeline sample.

TABLE 5: FLEXURE TEST RESULTS

Test No.	Cplg No.	Cplg Type	Pipe Type	Pipe End	Sub A Insert Depth (in)	Sub B Insert Depth (in)	Height (in feet) to 3rd Coupling When: Cplg Began to Bind Pipe	Permanent Deformation	*Remarks See Photos 20 & 21 for setup.
1	24	S800	MD261	PE	6.625	6.625	14	22	See Photo 22.
	31	"	"	"	"	"	N/A	N/A	
	34	"	"	"	"	"	N/A	N/A	
2	23	"	"	"	"	"	14.5	22	See Photos 23 & 24
	37	"	"	"	"	"	N/A	N/A	
	18	"	"	"	"	"	N/A	N/A	
3	17	"	"	DRG	5.50	"	17.75	20.5	See Photo 25.
	36	"	"	"	6.625	"	N/A	N/A	
	30	"	"	"	"	"	N/A	N/A	
4	25	"	"	"	"	"	15	21	See Photo 26.
	12	"	"	"	"	"	N/A	N/A	
	11	"	"	"	"	"	N/A	N/A	

*Note - The samples used in these tests were also used for the natural bend test. The natural bend failure at coupling 31 was re-assembled.

Photo #20: Flexure test setup.

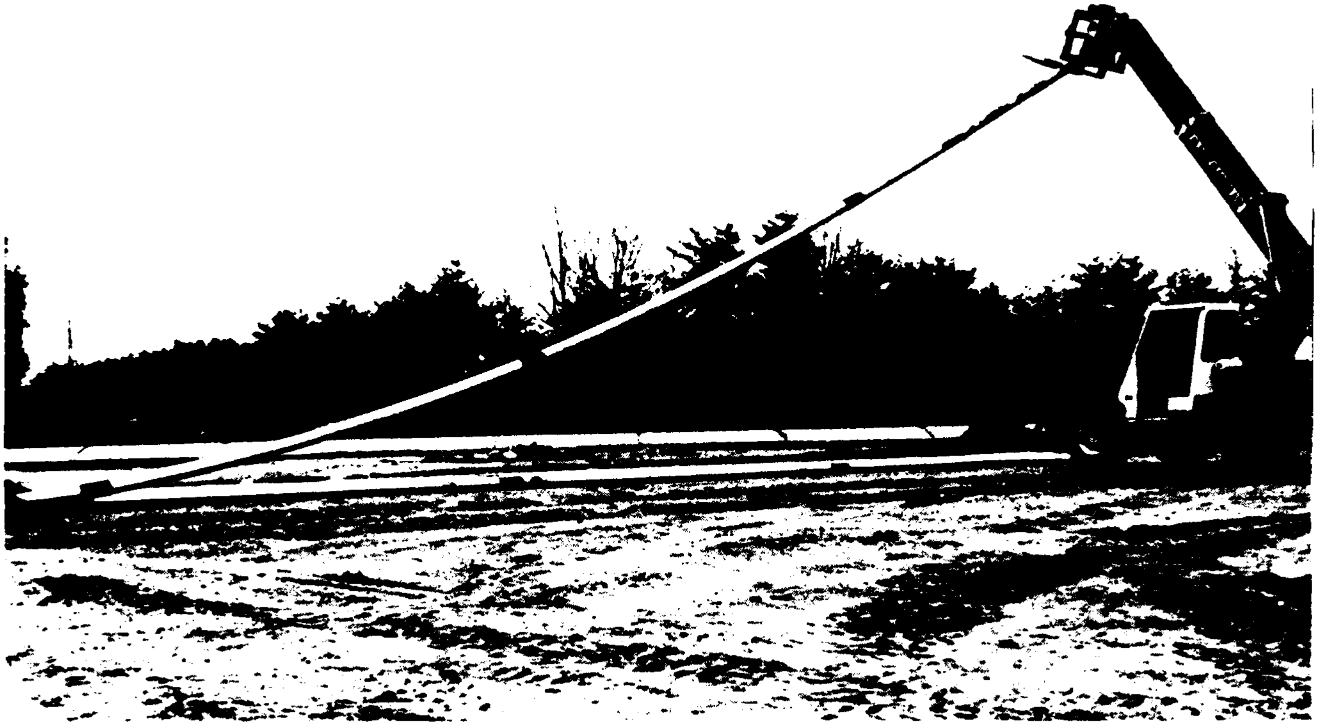
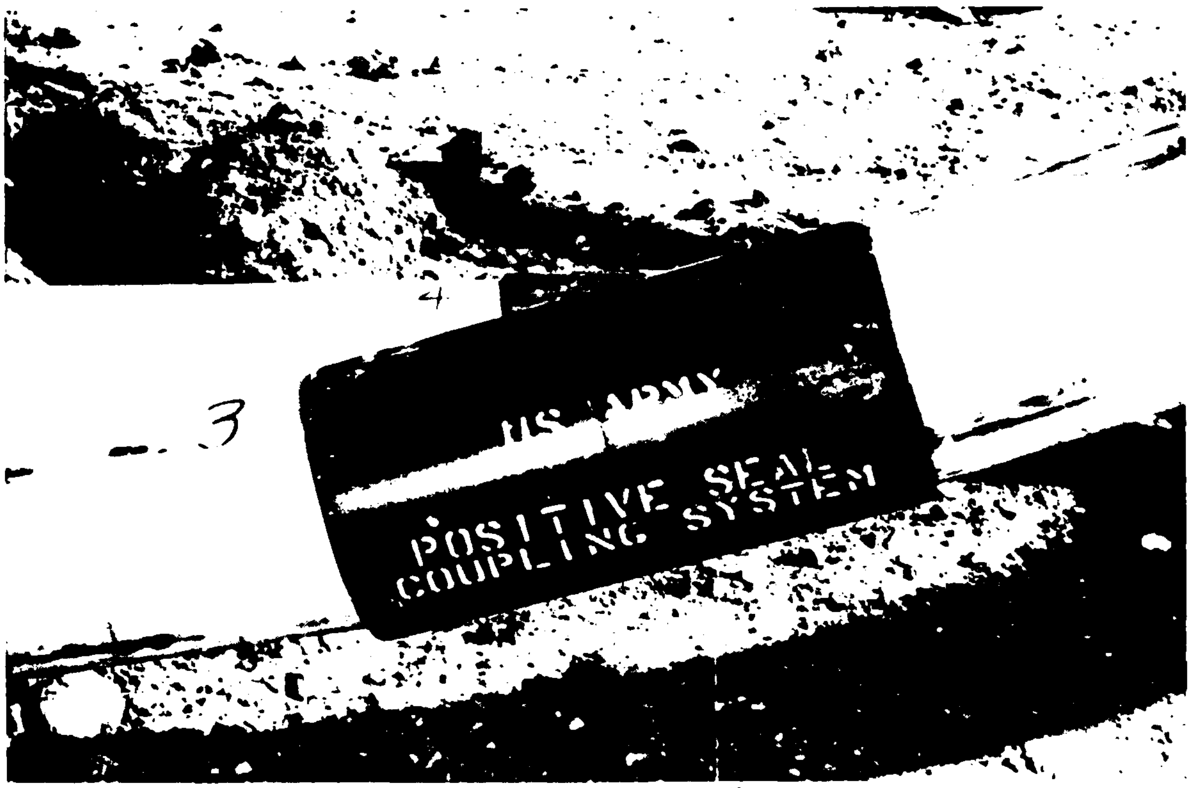


Photo #21: Flexure test #1. The high-reach fork lift could not lift high enough to cause buckling.

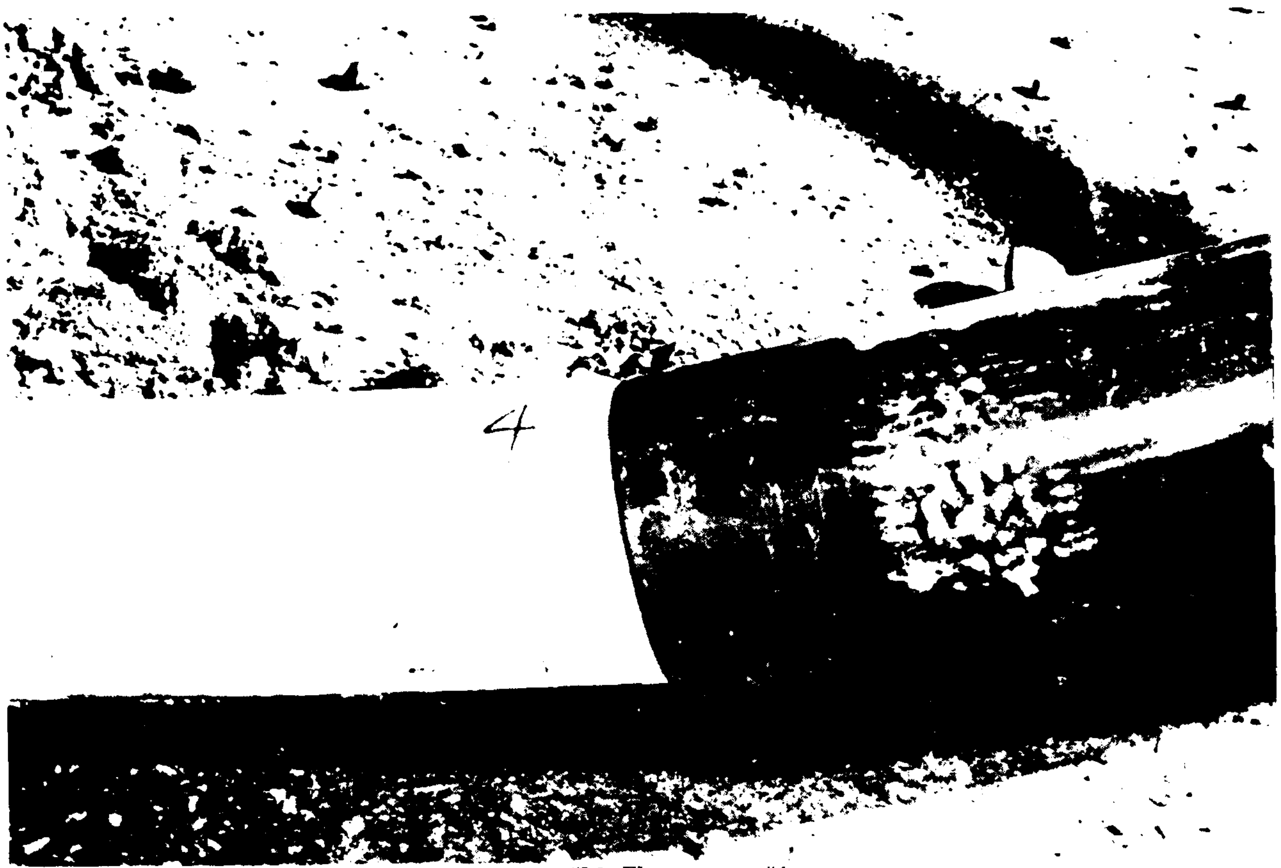
Photo#22: Flexure test #1.

Photo#23: Flexure test #2. showing setup and position of sample when buckling occurred.

Photo #24: Flexure test #2. after bending moment relieved. Shows deformation.



Photo#25: Flexure test #3.



Photo#26: Flexure test #4.

f. General:

For assembly of the test samples, we had to increase the hydraulic pressure to the press to the point where the insertion pressure and pipe clamping pressure gauges were pegged above their 1,500 psi limit.

During the assembly of many of the test samples, the jaws of the travelling slips scored the outside of the pipe walls. Conversation with the manufacturer revealed that these samples were not aligned properly before the slips were clamped around the pipe. For the System Integration Test at the Yakima Firing Range, the manufacturer will brief user personnel in proper operation of the hydraulic press and alignment of the pipe.

Note that the structural aluminum support for the travelling slips fractured during the make-up of the pressure test samples, and repair was necessary before other test samples were assembled. The press used to assemble the test samples had undergone extensive field and RAM testing, and the structural members may have been fatigued. Also, the increased hydraulic pressure required to drive the aluminum assault pipe into the coupling produced higher stresses than ICO designed the press to withstand.

7. CONCLUSIONS:

a. Although the aluminum press fitted with five-inch hydraulic cylinders has been used to join 0.109- and 0.150-inch wall aluminum pipe with Series 800 couplings, we believe that SWAPDOP needs a steel press with seven-inch cylinders to join the aluminum assault pipe of 0.188-inch wall thickness. The aluminum frame will not withstand forces generated by the seven-inch cylinders.

b. The Neutra Rust DL coating is superior to the epoxy coating because it is easier to use, requires less field work, and provides the proper sealing characteristics.

c. For simple, straight, hydrostatic applications, the Series 800 Positive Seal coupling will satisfy SWAPDOP needs; but if subjected to bending and pulling, its performance might be marginal.

d. Hydrostatic burst pressure in a system of assault pipe and Positive Seal couplings, with no bending or tensile loading, is limited by the yield strength of the pipe wall, not the pipe-coupling connection.

e. The safety factors for normal and emergency operations are three and two, respectively.

f. Double-rolled grooves in the pipe end have little effect on the joint's performance.

g. Sharp pipe ends tend to peel the coating from the inside wall of the couplings during insertion. Therefore, the pipe ends should be lightly filed to round the outside edge and to remove any burrs.

h. Partial insertion of the pipe into the coupling does not mean a weaker joint. Contrarily, given a constant force produced by the hydraulic cylinders, the joint with partial insertion might be tighter because the insertion motion has been stopped by the interference between the pipe and coupling taper. The Series 800 coupling has a no-go shoulder at its midpoint that stops the insertion motion, whether or not the joint is tight (e.g., tolerances allow the pipe to be slightly undersized and the coupling to be slightly oversized).

APPENDIX A

TEST PLAN

TEST PLAN
for the
PIPELINE OUTFIT, PETROLEUM (POP)

1. INTRODUCTION:

The Action Officer Work Group 11 (AOWG 11) recently decided to accept the Pipeline Outfit, Petroleum (POP) for type classification, pending further testing to determine if the system is applicable for gap, river, and/or tunnel crossings. The system is commercially available, therefore, a Non-Developmental Item (NDI) approach was taken to meet the need for lightweight, rapidly-deployable, large-diameter piplines for distribution of fuel in the theatre of operations. Between 15 Oct and 28 Nov 1982, The Engineer Test Division of the US Army Armor and Engineer Board, Fort Pickett, VA, conducted the Force Development Test and Evaluation (FDTE) of the POP system in order to assess its operational effectiveness. Results from the FDTE showed that the system met or exceeded the target layrate during daylight assembly. The AOWG requested that additional testing be conducted to determine the POP's complete operational characteristics before type classification.

This test plan describes the purpose, equipment requirements, procedure, and acceptance criteria for each test. The goal of the testing program is to evaluate the performance of the POP when subjected to high pressure, tensile loading, and bending. The pressure testing will be conducted to find if the system can withstand high pressures such as those experienced during periods of abnormally high fuel demands. The remainder of the testing will aid in determining the suitability of the POP system for crossings (gap, river, tunnel, etc). All tests will be performed on both pipe with plain ends and on pipe with double rolled groove ends, each connected with positive seal couplings.

2.0 PRESSURE TESTING:

2.1 Purpose:

Results of the pressure testing will indicate if the pipe and coupling can seal against pressures of 650 psig working, 900 psig emergency, and 1,064 psig proof. Also, by increasing the pressure until the assembly bursts, the safety factors for normal and emergency operations may be calculated.

2.2 Equipment & Setup:

Equipment for each run of this test will consist of 1 Positive Seal coupling coated with Neutra Rust DL; 2 sections of 6.625-inch O.D., 0.188-inch wall, MD261 aluminum assault pipe; 2 end caps; 1 bleeder valve; 1 pressure gauge; and 1 water pump capable of producing 2,000 psig. The end caps will be tapped to accommodate the valve, gauge, and pump.

2.3 Procedure:

The POP joining press will be used to make the pipe connection from the two pipe sections and one coupling. The entire assembly will be placed in the confined testing area and filled with water. During the filling process, the bleeder valve will be open so that air can be purged from the system. Hydrostatic pressure of 650 psig will be exerted on the system for 5 minutes, increased to 900 psig for 5 minutes, increased to 1,064 psig for 5 minutes, and finally increased until failure.

2.4 Acceptance Criteria:

Any evidence of leaking prior to burst will constitute failure of this test. If the pipe with double-rolled grooves passes this test, it will be used for all subsequent testing. Otherwise, plain end pipe will be used unless it has failed the test. The latter condition will preclude any further testing.

3.0 TENSILE TESTING — LAB:

3.1 Purpose:

This test will be preliminary to tensile testing in the field and will be conducted to determine the equipment necessary for successful field testing. However, it will give an indication of the tensile strength of the POP joint under ideal laboratory conditions.

3.2 Equipment & Setup:

The lab test will consist of two, short pipe "subs" connected by the Positive Seal coupling coated with Neutra Rust DL. The two ends will be anchored into a Baldwin tension/compression frame. The frame is equipped with a maximum force gauge and a chart recorder that plots applied sress versus strain.

3.3 Procedure:

Increasing tensile stress will be applied until there is movement between either pipe sub and the coupling. The maximum force required to initiate the slippage will be noted and logged into the results along with the stress vs. strain diagram.

3.4 Acceptance Criteria:

Because there has been no standard established, there are no acceptance criteria. The results will help define the system's limiting parameters.

4.0 TENSILE TESTING — FIELD:

4.1 Purpose:

Critical to the acceptance of the POP is the joint's ability to maintain a fluid-tight seal after being pulled, dragged, or lifted into place over gap or river crossings. During such procedures, the pipeline would not be pressurized. Therefore, the pull test will be performed under atmospheric pressure to evaluate the POP's suitability for crossings.

4.2 Equipment & Setup:

Each sample for this test will consist of a four-section pipe assembly, 80 feet long and either three or five couplings, depending upon the results of the lab tensile test. If the aluminum pipe wall can withstand the force, 2-inch holes will be drilled through the pipe, 3.75 inches from each end, and a steel rod will be inserted through the pipe walls and through a clevis connected to pulling cables. If the pipe wall cannot withstand the stress, couplings will be prepared to receive the pulling cables and then swaged onto the ends of the pipe assembly. Also required are a crane and a dynamometer truck equipped with a chart recorder that measures applied stress versus displacement.

4.3 Procedure:

The assembly will be anchored to a deadman at one end and fastened to the dynamometer truck at the other end. Near the center of the pipeline assembly, a sling or choker will be wrapped around the pipe and attached to the crane's lifting line. The crane will simulate conditions that might be encountered when making a crossing by alternately raising and lowering the pipeline to induce flexing. The tensile load will be increased until a pipe joint fails. The chart recorder is located in the truck and will plot a stress vs. strain diagram that will show the point of failure.

4.4 Acceptance Criteria:

As with the lab portion of the tensile test, there are no acceptance criteria. Knowledge gained from this test will aid in comparing the POP's limitations with those of the welded-steel and snap-joint coupling systems and in selecting the most appropriate system for crossings.

5.0 NATURAL BEND TESTING:

5.1 Purpose:

This test will be conducted to aid in the determination of the maximum crossing width the POP system can successfully span while subjected to an internal working pressure of 650 psig. Also, it may be helpful for determining the minimum number of side-boom cranes required to carry a pipeline over a crossing.

5.2 Equipment & Setup:

Four sections of pipe will be coupled together, and end caps will be attached. Also required are the water pump, bleeder valve, the pressure gauge used in the pressure testing, and a crane.

5.3 Procedure:

Once the pipe and couplings have been assembled via the POP joining machine, one end of the assembly will be raised by the crane until at least two couplings are off the ground and the system has assumed an unrestrained, natural bend. Then, the system will be filled with water and pressurized to 650 psig, being certain to vent the air from the system and keep two couplings off the ground.

5.4 Acceptance Criteria:

Any leaking from the assembly will constitute failure of this test.

6.0 FLEXURE TESTING:

6.1 Purpose:

Results from the flexure testing will determine the maximum bend a pipeline assembled with the POP can withstand without buckling the aluminum pipe or causing failure at the joint.

6.2 Equipment & Setup:

The same four-joint assembly that was used in the natural bending test will be used here. Also required are a crane and a bulldozer. Approximately 20 feet of the pipe assembly will be buried beneath a pad of dirt, and the bulldozer will be parked over the end-most portion of the pipe as an anchor.

6.3 Procedure:

The crane will raise the free end of the assembly, via cable, until there is evidence of buckling in the pipeline or slippage at the coupling. A dynamometer fixed in the cable will record the force required to initiate failure. The maximum deflection will be measured in feet per foot of pipeline.

6.4 Acceptance Criteria:

As with the tensile testing, there is no standard established to govern the test results. Therefore, the information gathered from the testing will aid in comparing the POP's limitations with the limitations of other pipeline systems used by the Army.

7.0 DOCUMENTATION

All test data, stress vs. strain diagrams, descriptions of the equipment, and procedures for each test will be recorded. Photographs of each test will be taken.

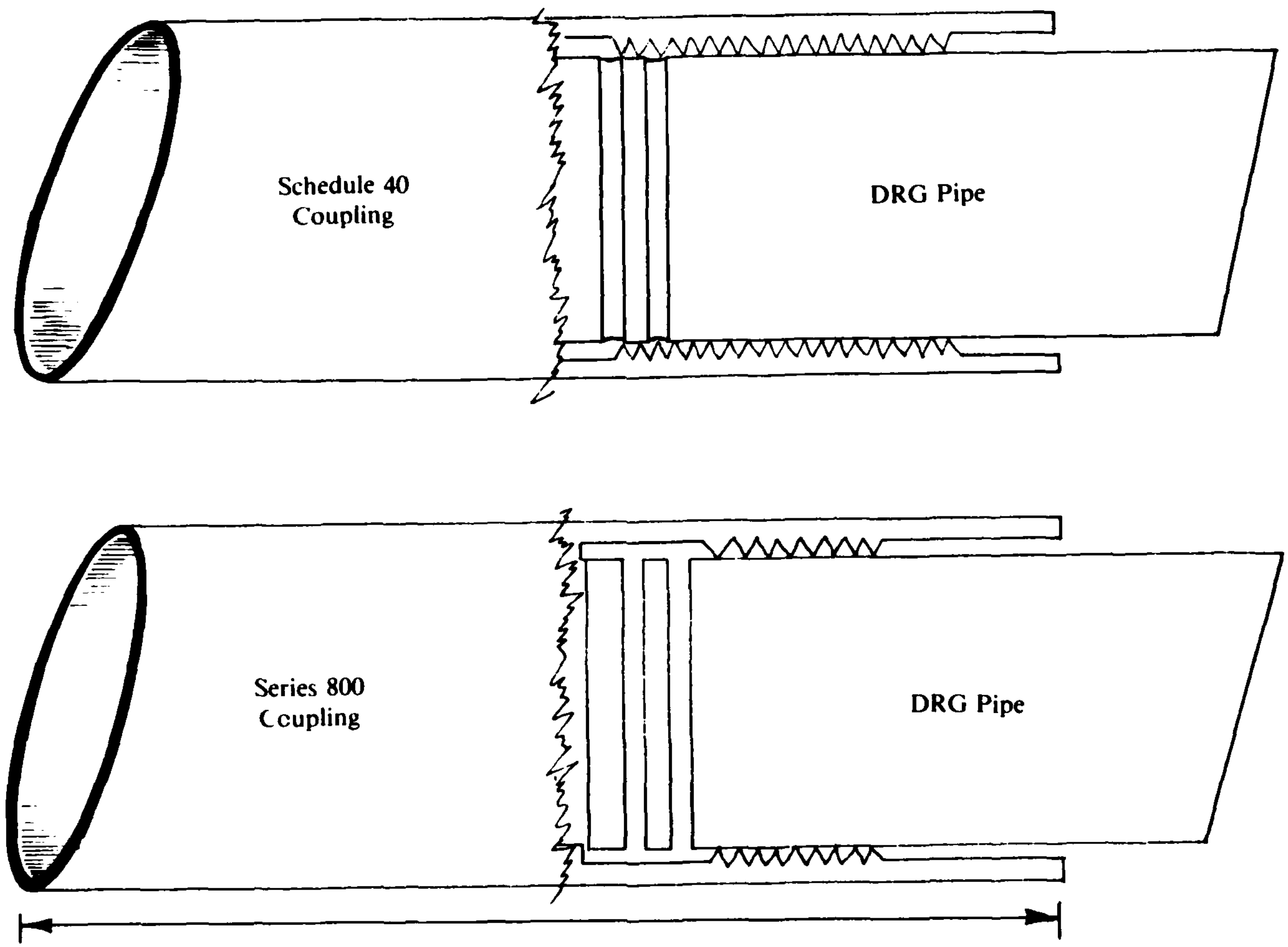
A formal report will document the entire testing program and include conclusions and/or recommendations.

APPENDIX B

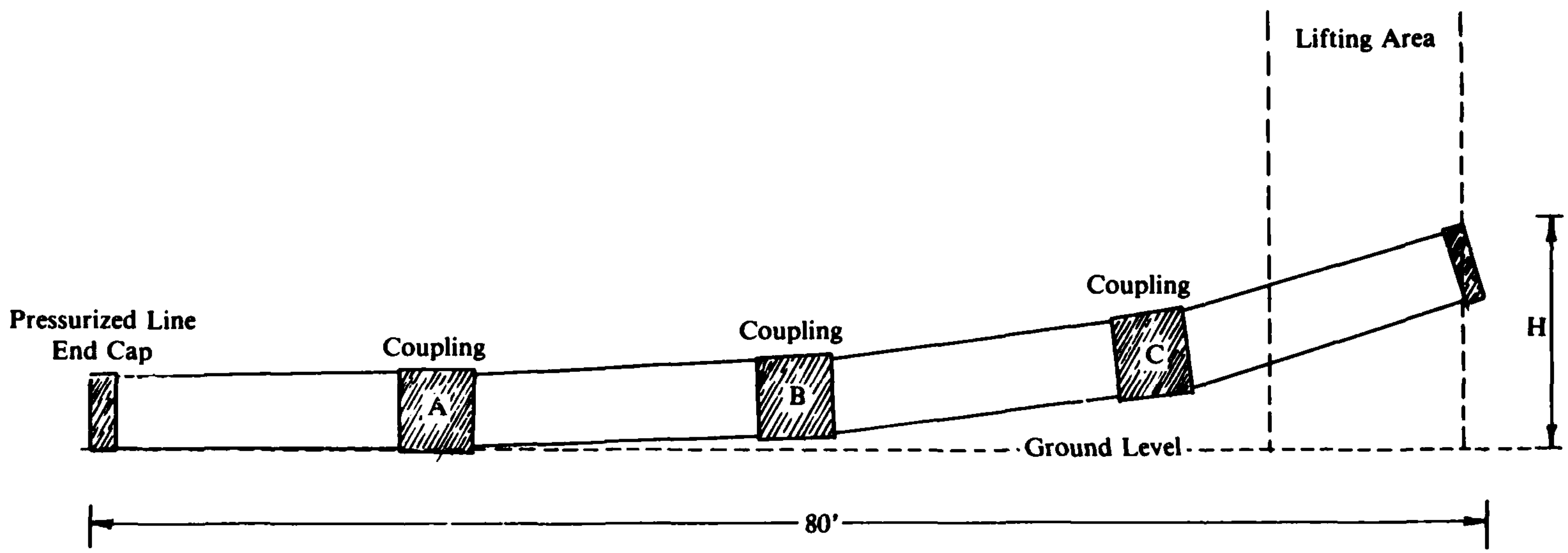
FIGURES

POSITION OF DOUBLE-ROLLED-GROOVES (DRG) RELATIVE TO SERRATED PORTION OF POSITIVE SEAL COUPLINGS

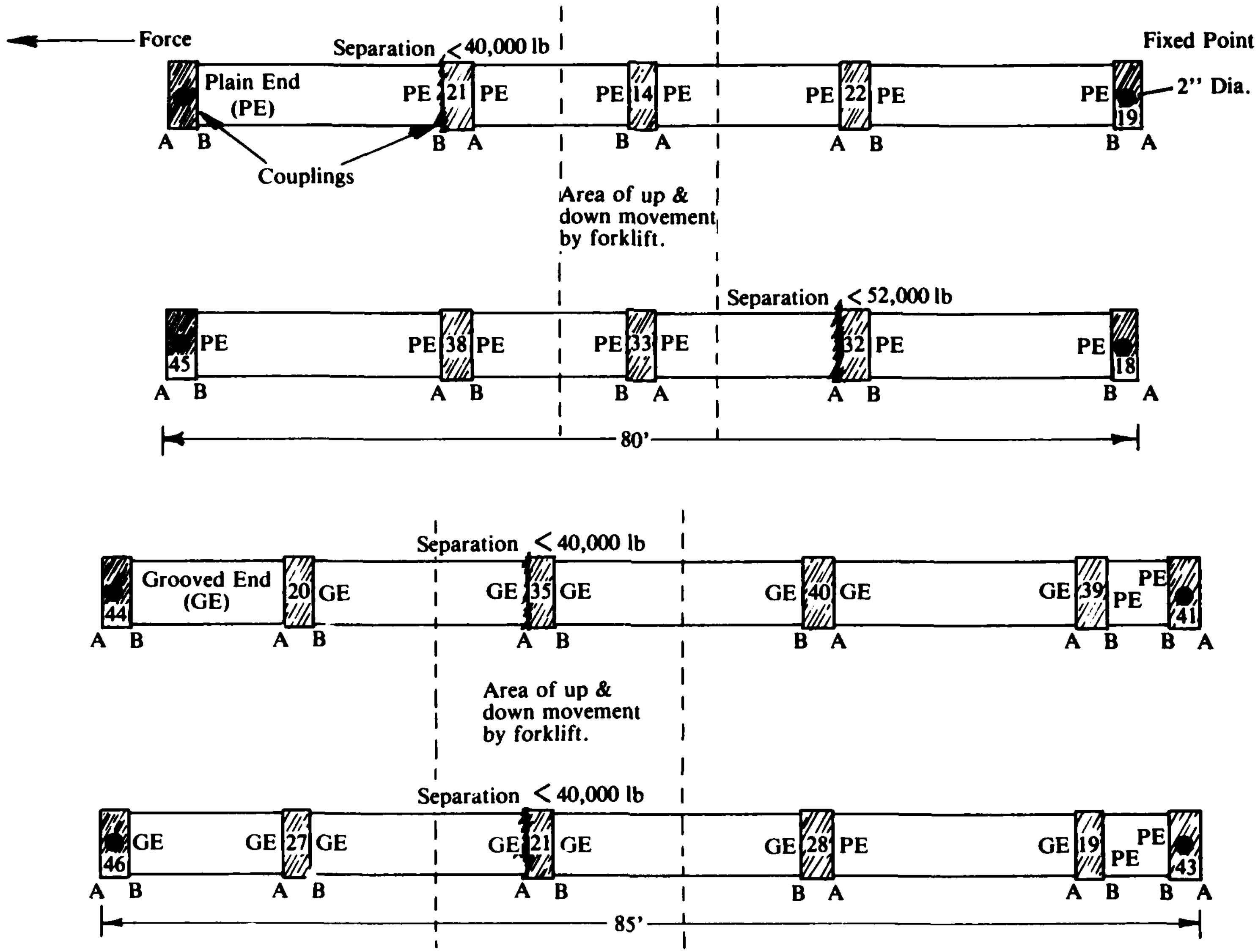
FIGURE 1



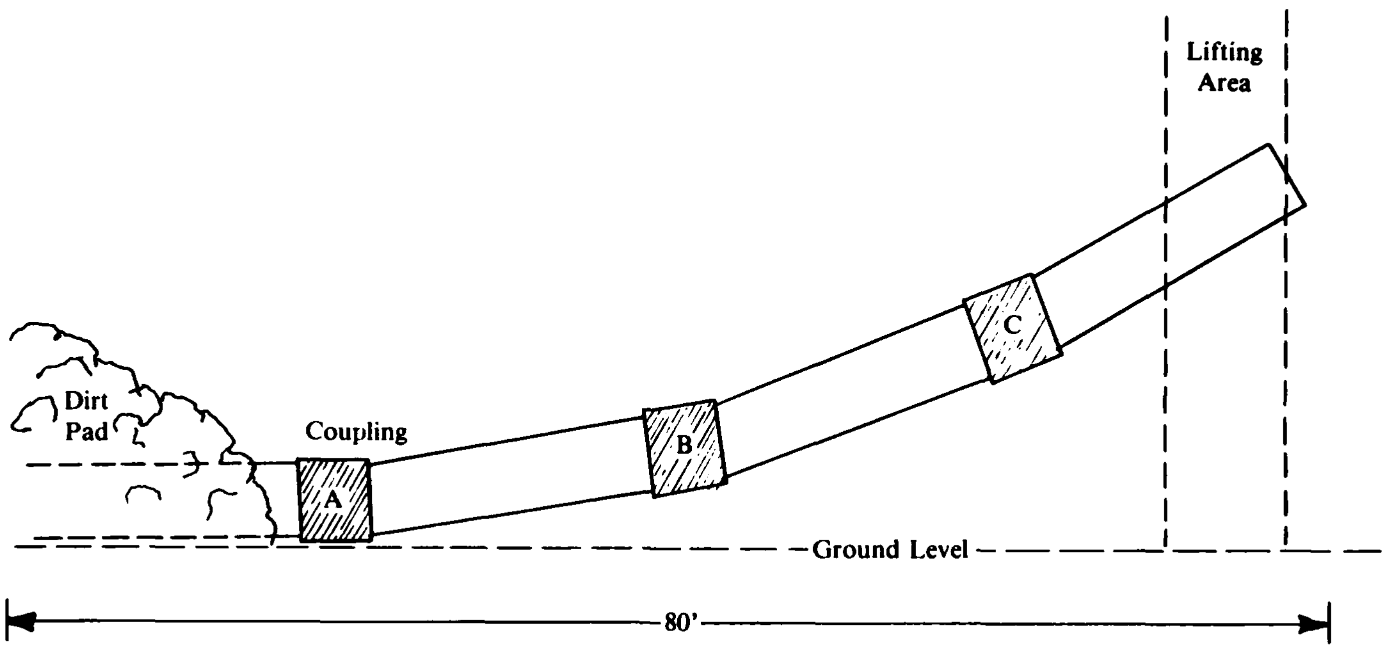
NATURAL BENDING
FIGURE 2



TENSILE PULL-FIELD
FIGURE 3

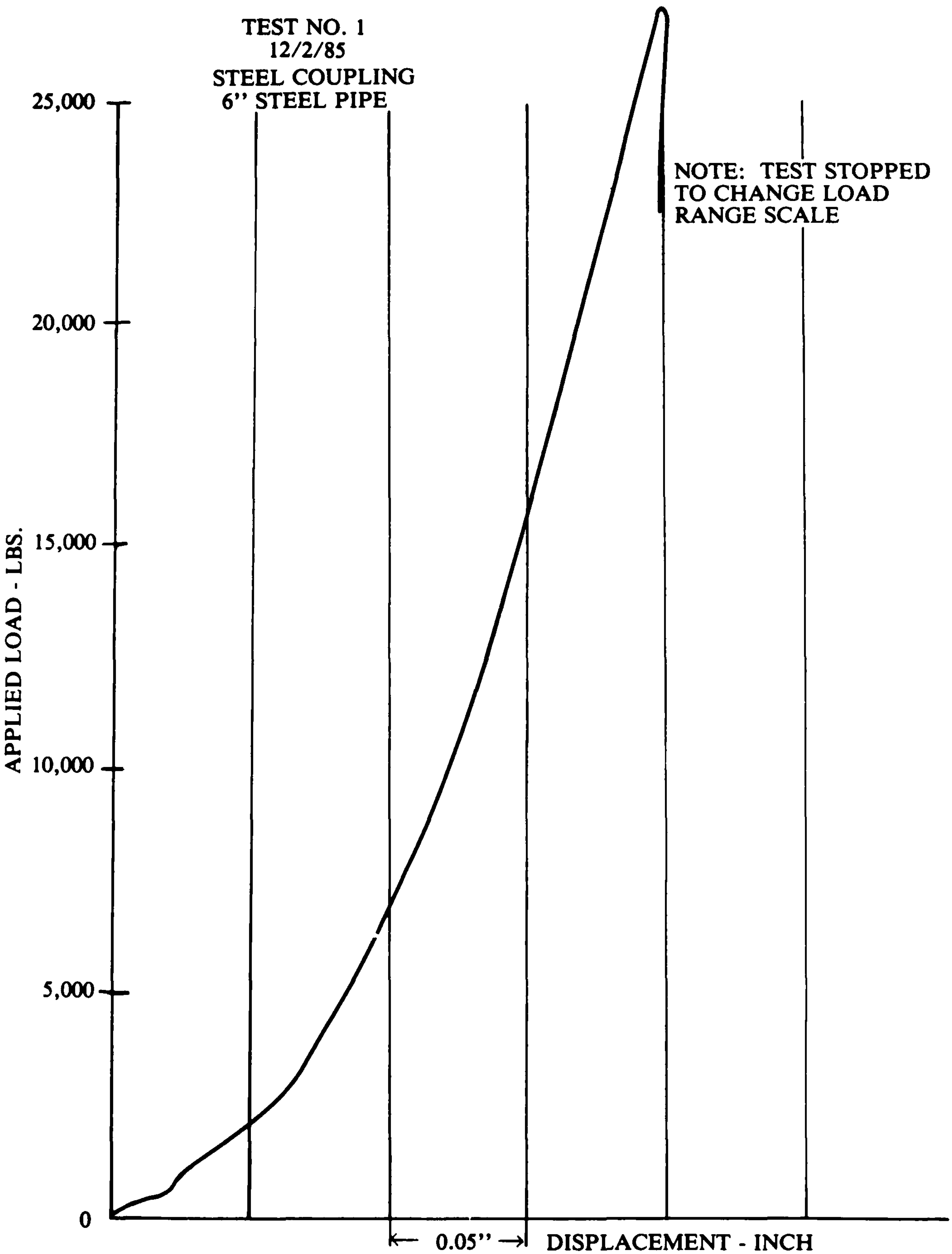


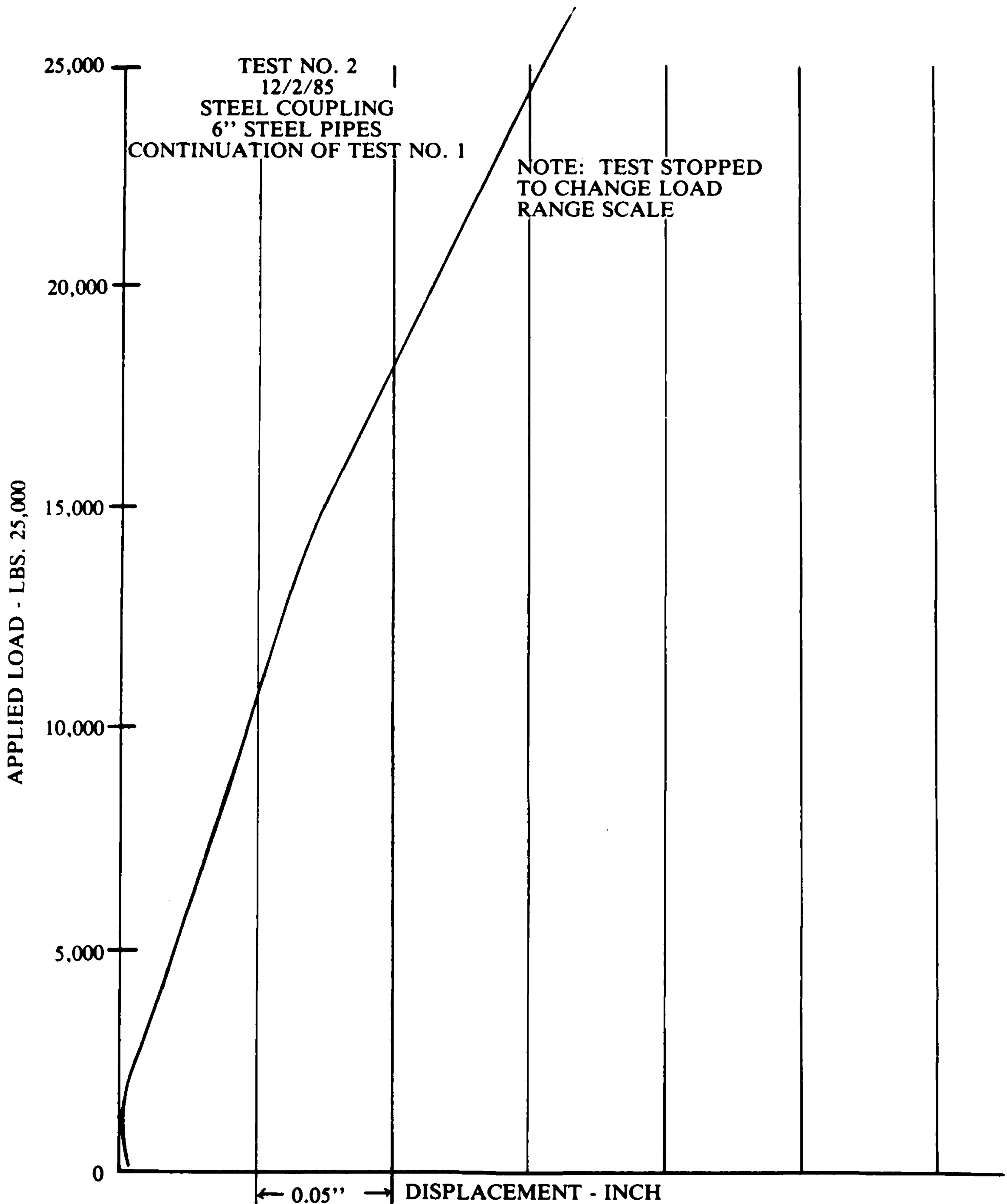
FLEXURE
FIGURE 4



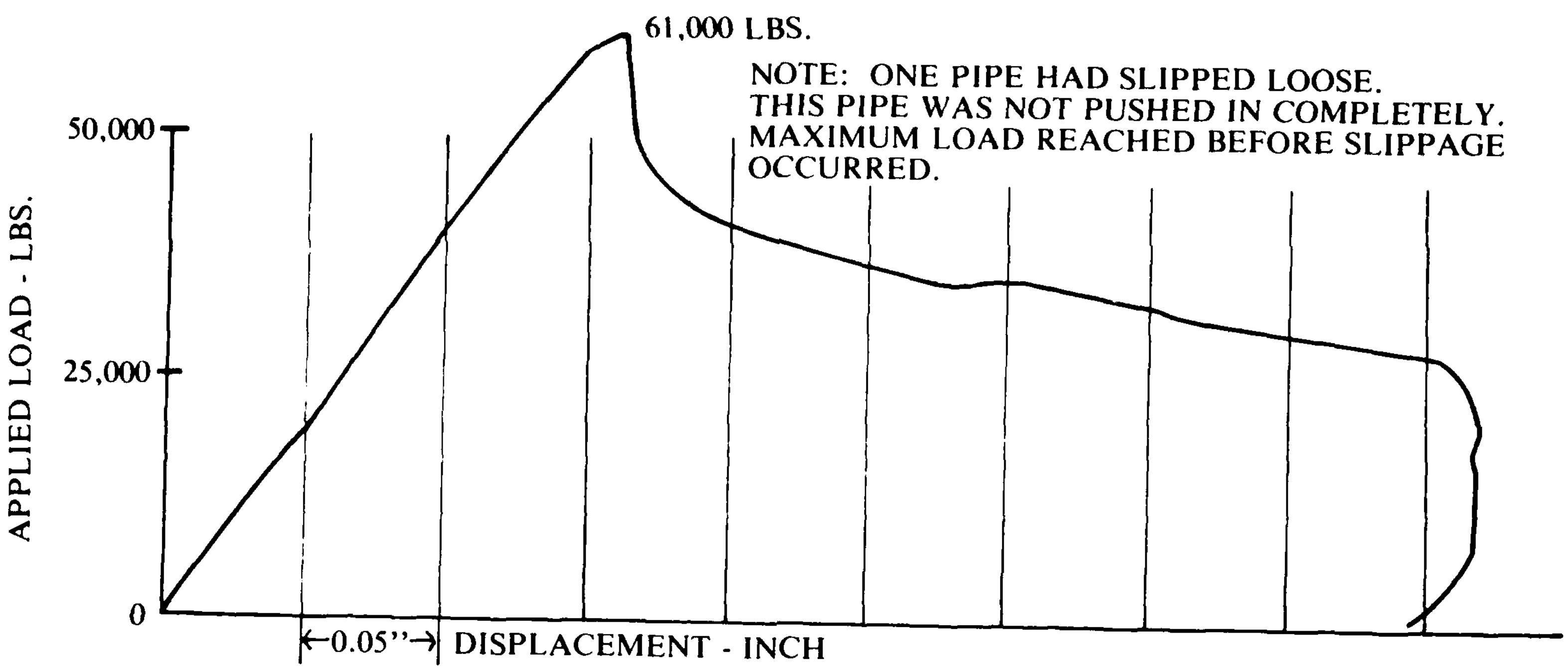
APPENDIX C

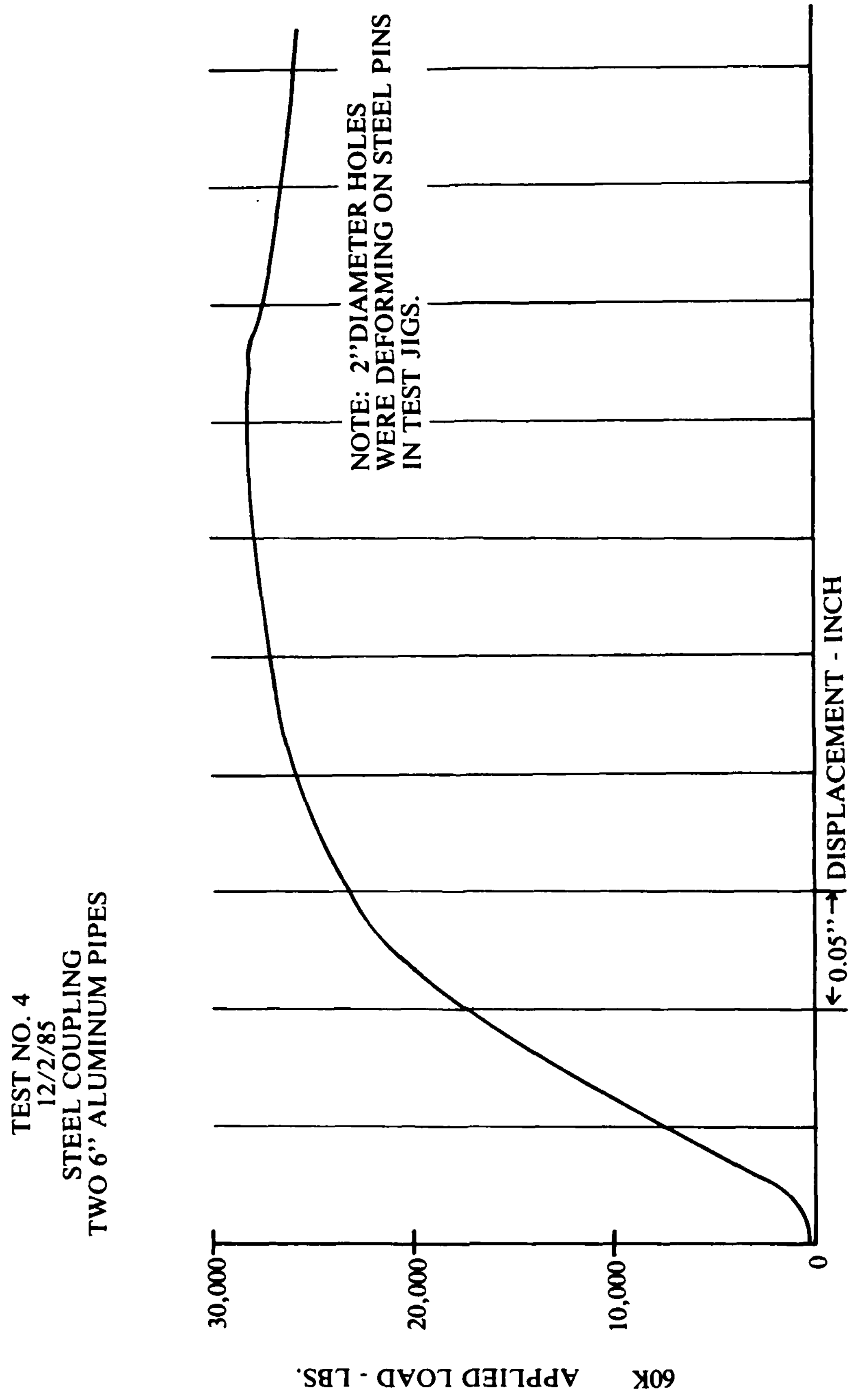
STRESS vs. STRAIN DIAGRAMS

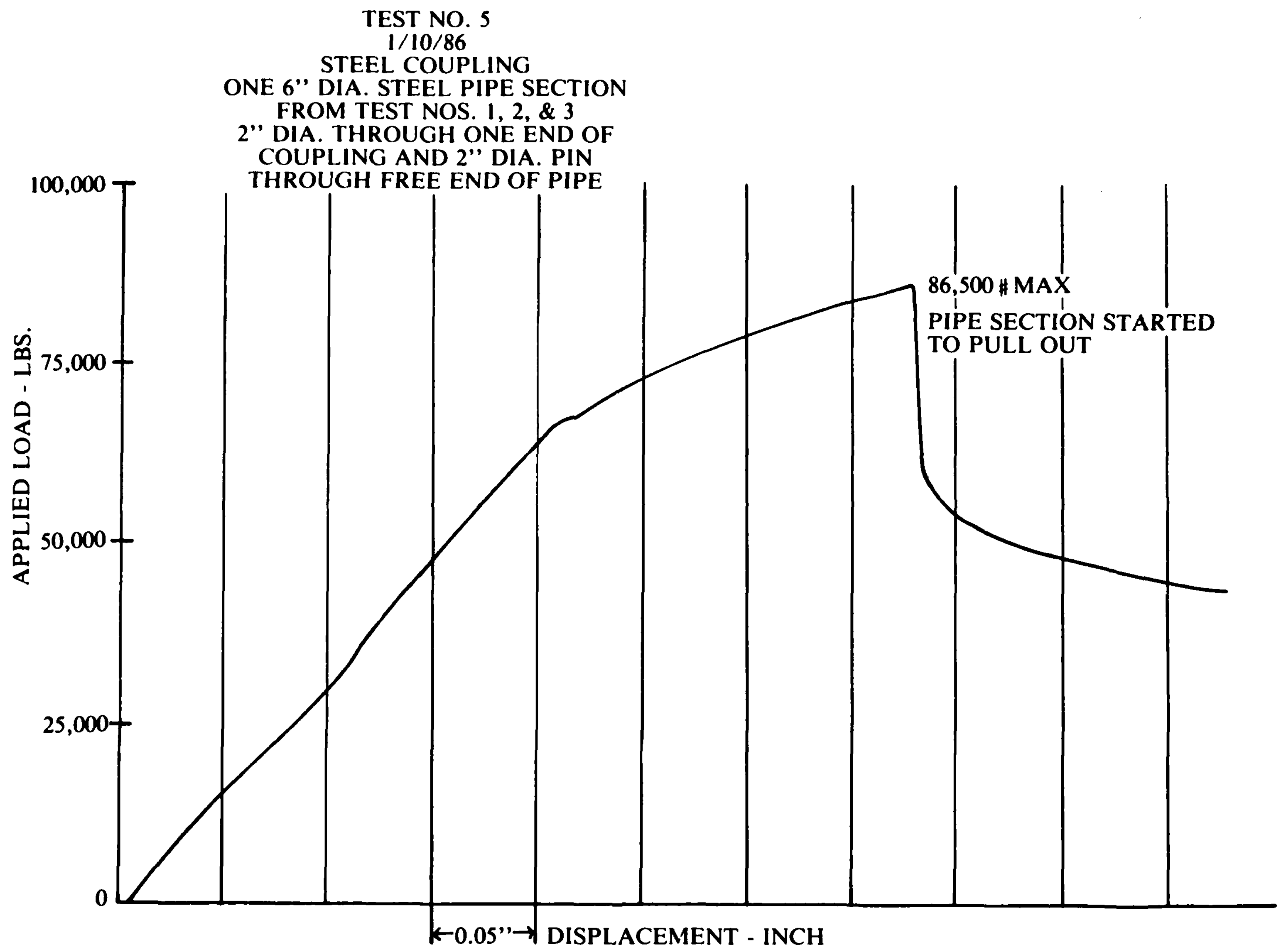

TEST NO. 1
12/2/85
STEEL COUPLING
6'' STEEL PIPE
25,000
20,000
15,000
10,000
5,000
0
APPLIED LOAD - LBS.
NOTE: TEST STOPPED TO CHANGE LOAD RANGE SCALE
0.05''
DISPLACEMENT - INCH

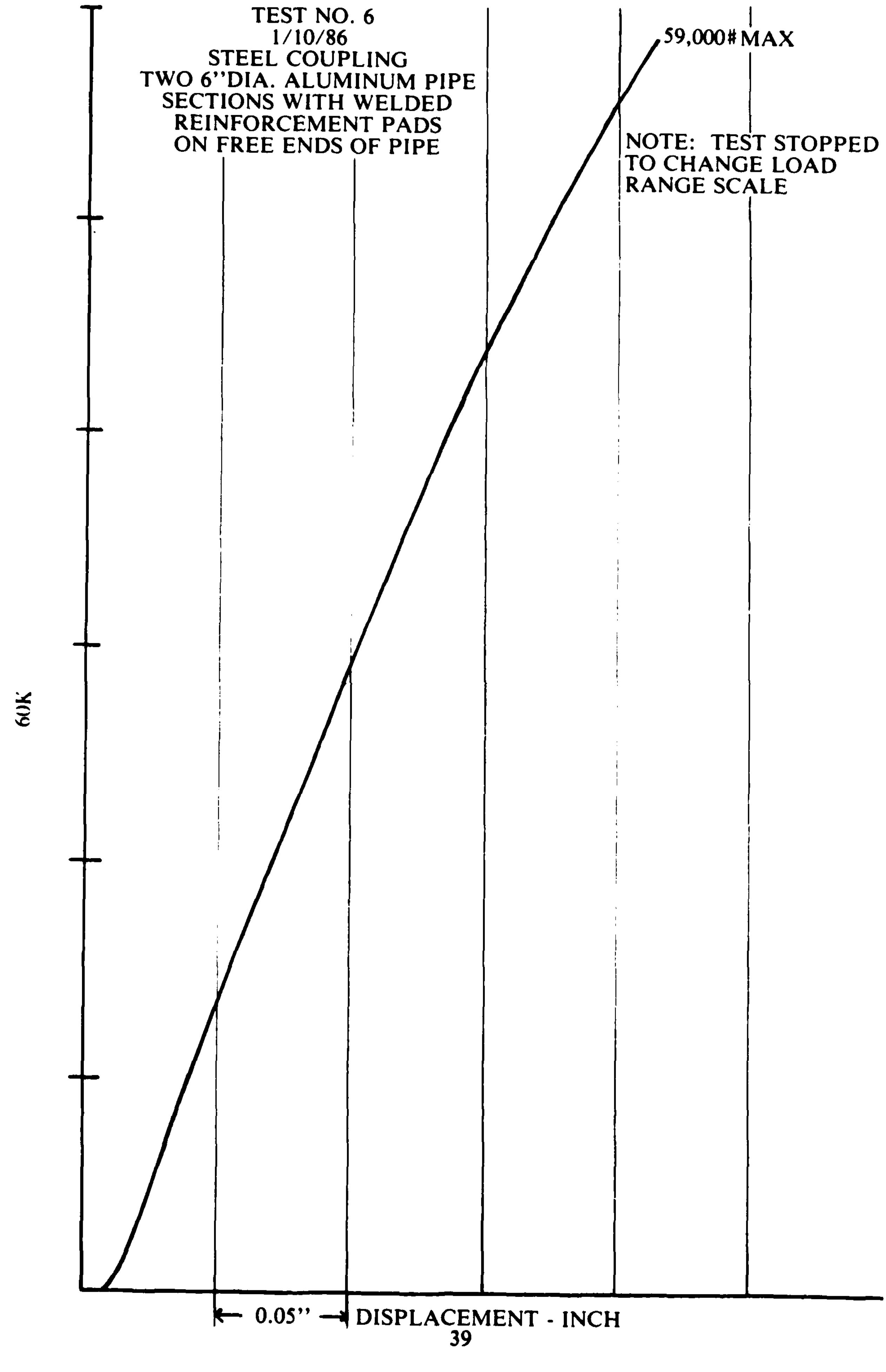

TEST NO. 2
12/2/85
STEEL COUPLING
6" STEEL PIPES
CONTINUATION OF TEST NO. 1
NOTE: TEST STOPPED
TO CHANGE LOAD
RANGE SCALE
25,000
20,000
15,000
10,000
5,000
0
APPLIED LOAD - LBS. 25,000
0.05"
DISPLACEMENT - INCH

TEST NO. 3
12/2/85
6" STEEL PIPES
STEEL COUPLING
CONTINUATION OF
TEST NO. 1

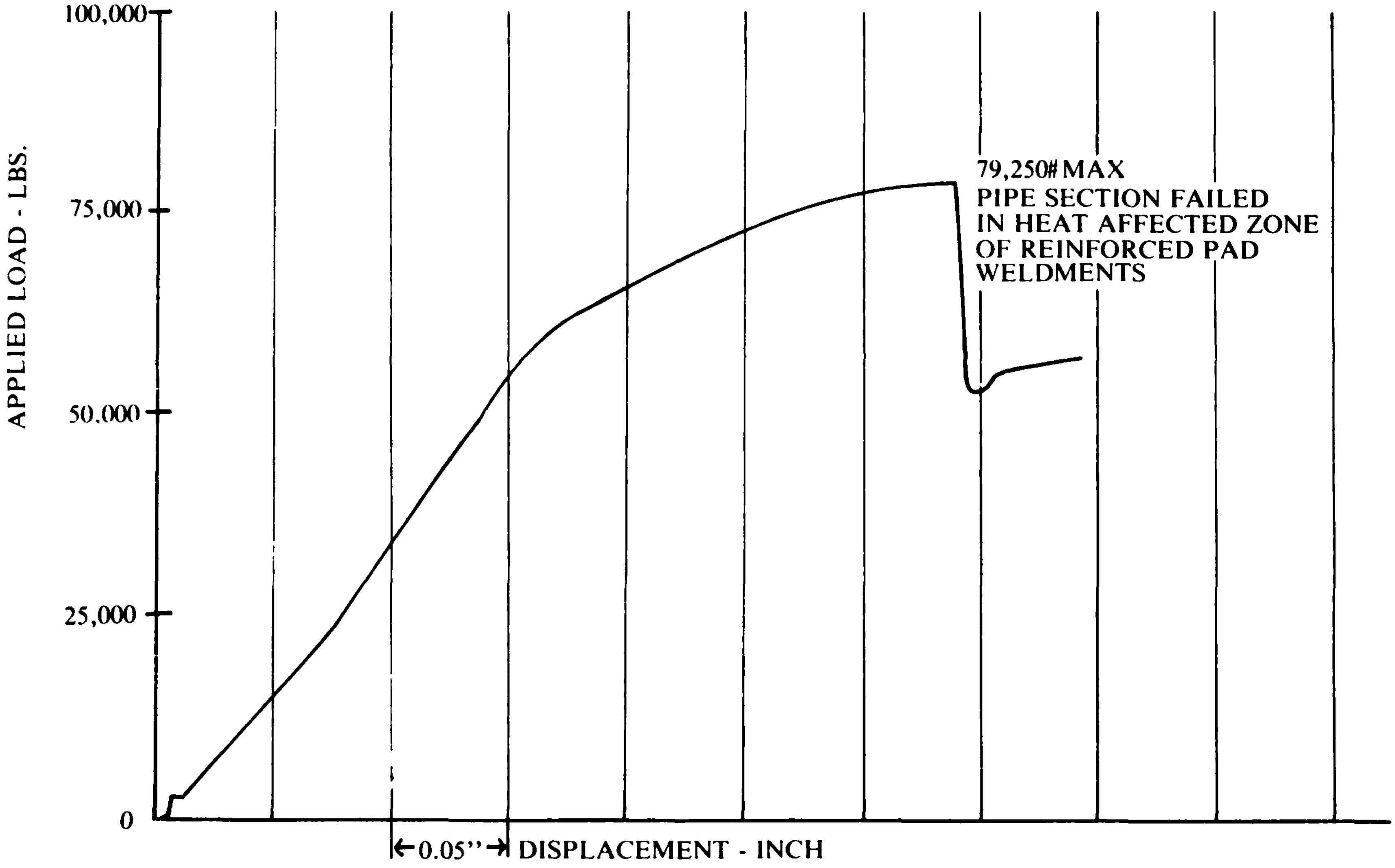



TEST NO. 4
12/2/85
STEEL COUPLING
TWO 6'' ALUMINUM PIPES
NOTE: 2''DIAMETER HOLES
WERE DEFORMING ON STEEL PINS
IN TEST JIGS.
30,000
20,000
10,000
0
← 0.05'' → DISPLACEMENT - INCH
APPLIED LOAD - LBS.
60K

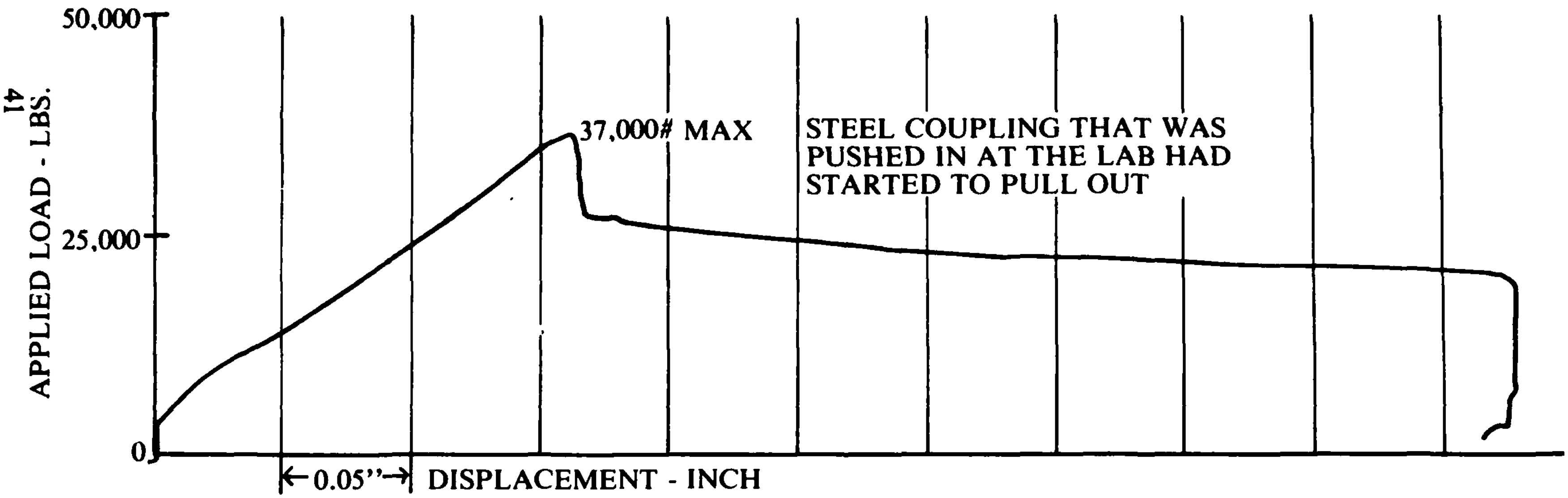

TEST NO. 5
1/10/86
STEEL COUPLING
ONE 6" DIA. STEEL PIPE SECTION
FROM TEST NOS. 1, 2, & 3
2" DIA. THROUGH ONE END OF
COUPLING AND 2" DIA. PIN
THROUGH FREE END OF PIPE
100,000
75,000
50,000
25,000
0
APPLIED LOAD - LBS.
86,500 # MAX
PIPE SECTION STARTED
TO PULL OUT
0.05"
DISPLACEMENT - INCH


TEST NO. 6
1/10/86
STEEL COUPLING
TWO 6"DIA. ALUMINUM PIPE
SECTIONS WITH WELDED
REINFORCEMENT PADS
ON FREE ENDS OF PIPE
59,000# MAX
NOTE: TEST STOPPED
TO CHANGE LOAD
RANGE SCALE
60K
0.05"
DISPLACEMENT - INCH

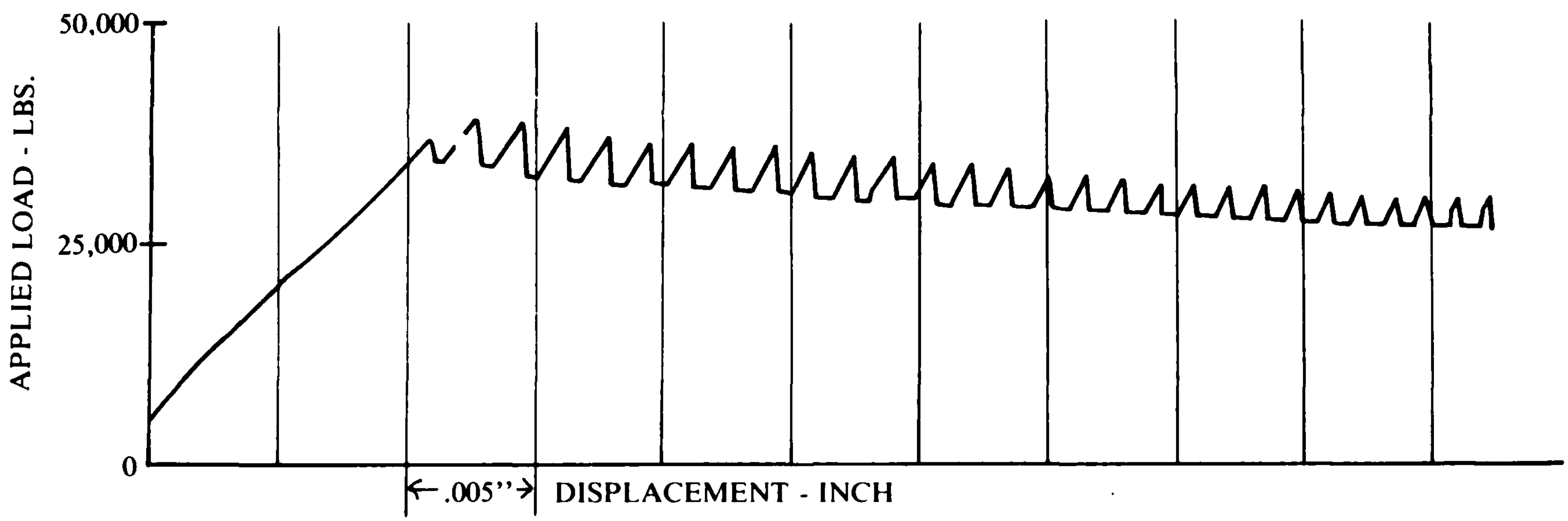
TEST NO. 7
1/10/86
STEEL COUPLING
TWO 6" DIA. ALUMINUM PIPE SECTIONS
WITH WELDED REINFORCEMENT PADS ON
FREE ENDS OF PIPE
CONTINUATION OF TEST NO.6



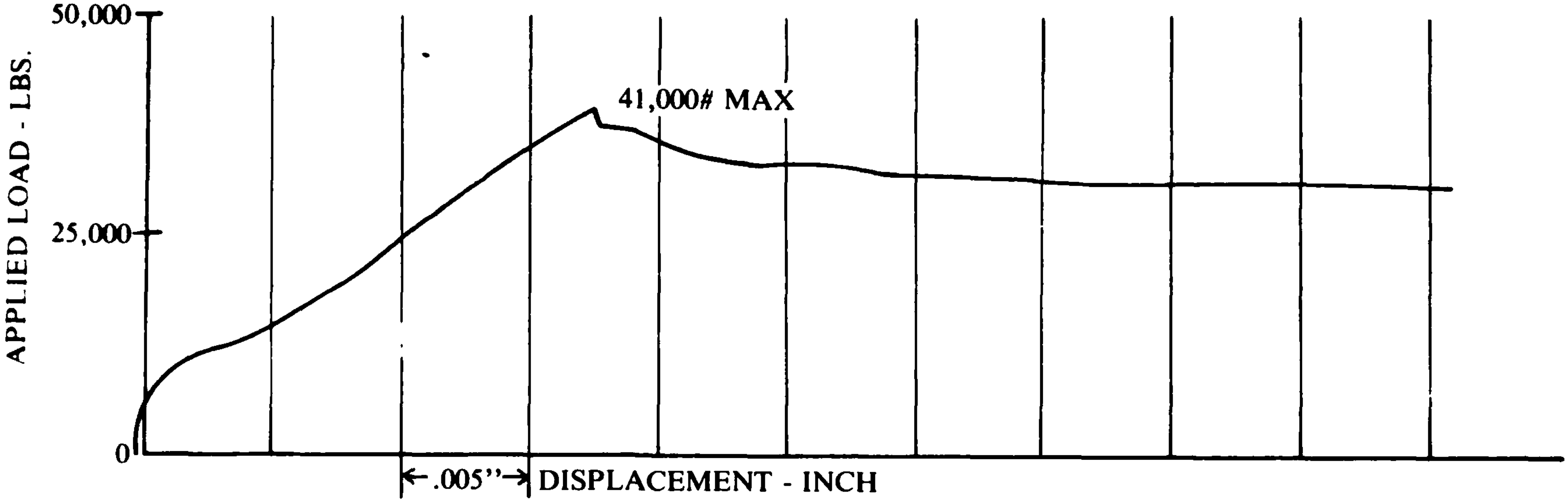
TEST NO. 8
1/21/86
THIN STEEL COUPLING
ON END OF A 6" DIA.
ALUMINUM PIPE. ONE OF
THE STEEL COUPLINGS WAS
PUSHED IN AT THE LAB.
LOAD WAS AS HIGH AS #
WAS REQUIRED TO PUSH THE
COUPLING INTO THE END OF TUBE.



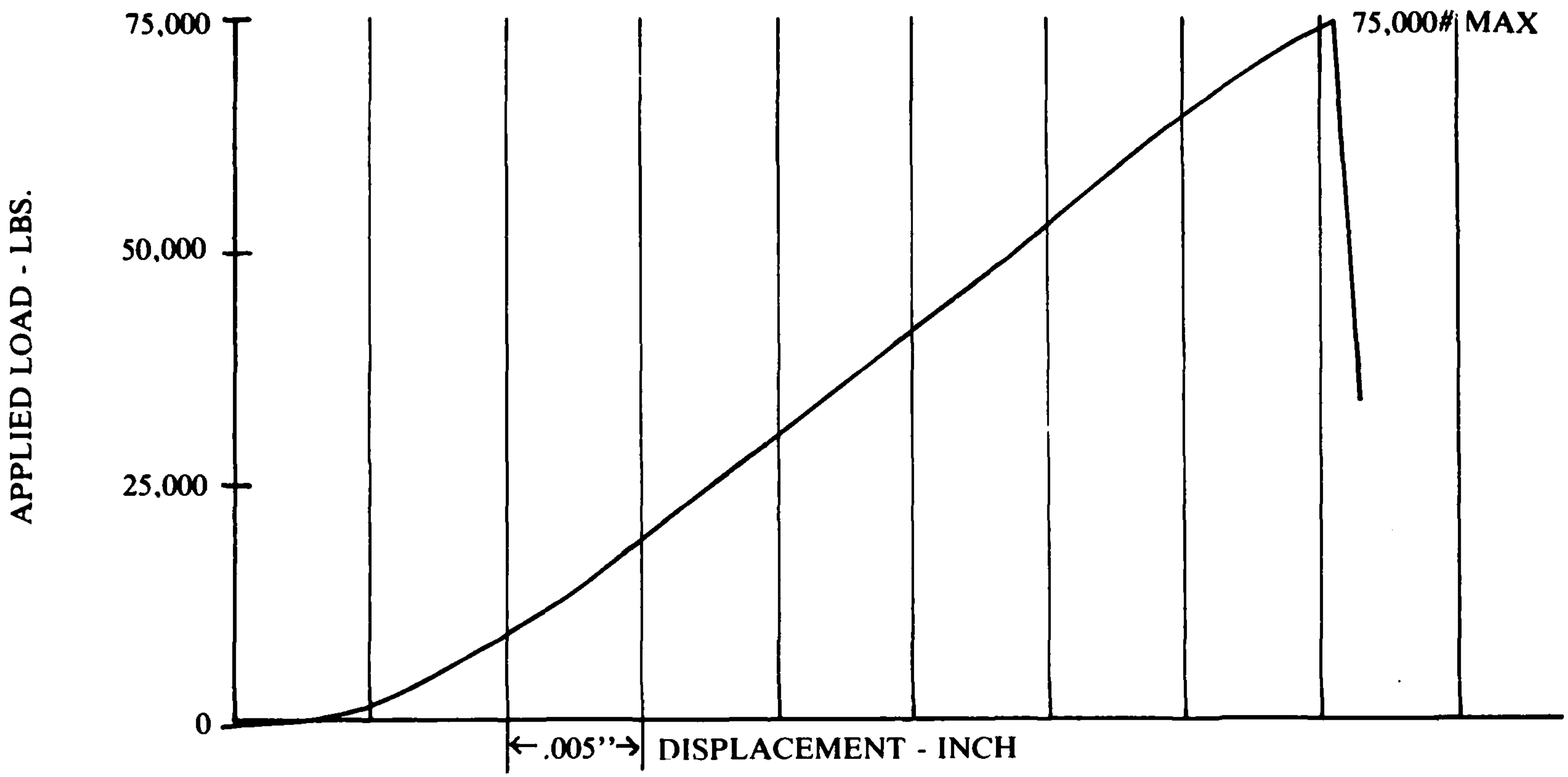
TEST NO. 9
2/1/86
THIN WALL COUPLING IN EACH END OF A 6''DIA. ALUMINUM PIPE. SAME PIPE WAS TESTED IN TEST NO. 8. FREE END OF PIPE WAS PUSHED INTO THE COUPLING AT THE LAB.



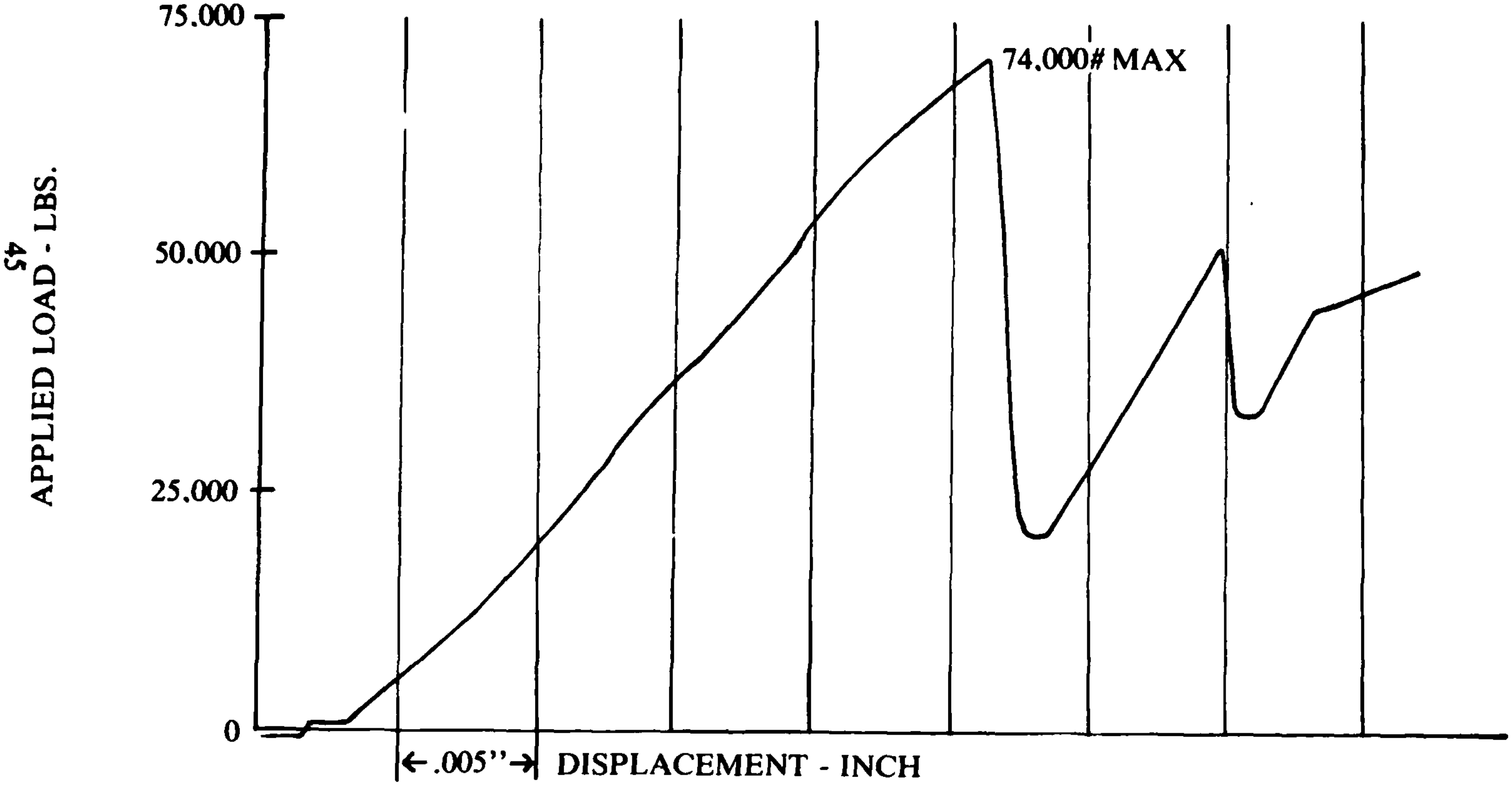
TEST NO. 10
2/1/86
THICK WALL COUPLING IN
EACH END OF A 6" DIA.
ALUMINUM PIPE. PIPE WAS
PUSHED INTO THE COUPLING
AT THE LAB.



TEST NO. 11
3/7/86
THIN STEEL COUPLING IN ONE END OF 6" DIA. ALUMINUM PIPE TESTED IN TEST NO. 9. FREE END OF TUBING WAS REINFORCED BY WELDING TABS ON OUTSIDE AND A DISC INSIDE THE TUBING.



TEST NO. 12
3/7/86
THICK STEEL COUPLING IN ONE END OF 6"DIA. ALUMINUM PIPE TESTED IN TEST NO. 10. FREE END OF TUBING WAS REINFORCED BY WELDING TABS ON OUTSIDE AND A DISC INSIDE THE TUBING.



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